

TALES ABOUT METALS



С. И. Венецкий

**РАССКАЗЫ
О МЕТАЛЛАХ**

**Издательство «Металлургия»
Москва**

S.Venetsky

TALES ABOUT METALS



Mir Publishers Moscow

First published 1981
Second printing 1988
Revised from the 1978 Russian edition

Translated from the Russian
by
N. G. Kittell

На английском языке

Printed in the Union of Soviet Socialist Republics

ISBN 5-03-000054-2 © Издательство «Металлургия», 1978
© English translation, Mir Publishers, 1981

Contents

About This Book	6
The Lightest Metal	7
Space-Age Metal	14
A Fighter Against Fatigue	21
Silver from Clay	28
Son of the Earth	38
"Vitamin V"	47
The "Red Lead" Mystery	54
Iron's Old Companion	63
A Great Toiler	71
The Charge of the Guns of Peace	83
"Copper Devil"	91
One of the Oldest and Celebrated Metals	100
A "Clothing" for Uranium Rods	111
The Forty First	118
Iron's Ally	125
Of a Noble Origin	133
"Hard" but ... Soft	144
Born "in Torment"	151
Giving Light	157
Behind Three Locks	165
The King of Metals and the Metal of Kings	173
Silver Water	186
The Metal that Destroyed Rome	193
The Fuel of the Twentieth Century	200

ABOUT THIS BOOK

For ages have metals faithfully served humanity in all its endeavours to conquer the elements, unravel the mysteries of Nature and build powerful machines and installations.

The world of metals is diverse and absorbing. The history of some of its representatives, notably, copper, iron, lead, mercury, gold, silver and tin dates thousands of years back. Others were discovered within just a few recent decades.

The properties of metals are extremely varied. Mercury will not freeze even at below-zero temperatures, while tungsten will not be consumed by the hottest of flames. Lithium could make a fine swimmer, being half as heavy as water and unable to sink no matter how hard it would try; osmium is a heavy-weight champion among metals and, thrown into water, will hit the bottom faster than a stone. Silver "gladly" conducts electricity, while titanium has an aversion to this "pastime": its electrical conductivity is only a 300th part that of silver. We come across iron wherever we turn and holmium is found in such minute quantities in the earth's crust that it is fabulously expensive: a grain of pure holmium is several hundred times more expensive than gold.

But for all their differences, metals have one thing in common—they all belong to one large family. S. I. Venetsky's *Tales About Metals* contains much information on the history of discovery of many metals and on their present and future uses.

It was not the author's idea to give any systematized account of every metal he tells about. The history of metals abounds in amazing incidents, at times romantic or humorous, at times tragic. And it is mostly this aspect that the author had in mind when he wrote his book.

The book is intended for those who are ever curious, not only youngsters who are just discovering the world of science for themselves, but also those who have probably said goodbye to school and college, but still seize upon every opportunity to learn more about things around them.

THE LIGHTEST METAL



In the prime of life.—A trip into the past century.—
The curative water of Karlsbad.—What is lighter?—
Vaseline baths.—Flyers put on life jackets.—A gout
cure.—Necessity is the mother of invention.—A dis-
play at the USSR Economic Exhibition.—No fear of
frost or heat.—Deep into the Antarctic.—A per-
manent lubricant.—Does glass taste good?—A blue
flame.—“The first violin”.—The outcome of a bom-
bardment.—Lithium “gulps down” neutrons.—Like
twenty Dnieper power plants.—Good old kerosene.—
Lithium vs. Lithium.—A crystal from South Dako-
ta.—“Open, sesame!”—A suspicious stew.

It was 150 years in 1967 since lithium, the first in the group of metals in the Mendeleev Periodic Table, had been discovered. In all this time it has not lost its importance and still is "in the prime of life". Enormous as its role in modern technology is, specialists do not believe that they know everything about this metal and predict a great future for it yet to come. But before going into that let us make a trip into the last century and look in at the quiet laboratory of the Swedish chemist Arvfedson. It is Sweden in the year 1817.

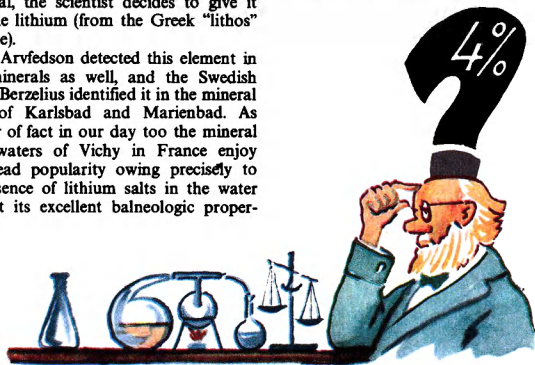
... For many days now the scientist has been busy analyzing the mineral petalite found at the Uto mine near Stockholm. He checks the results of his analysis again and again but each time the sum of all the components totals only 96 per cent. What happens to the remaining 4 per cent? Could it be that...? Yes, this must definitely be it: the mineral contains a hitherto unknown element. Arvfedson tries again and again. Finally he is satisfied: he has discovered a new alkali metal. And since, unlike its "close relatives" potassium and sodium which were first discovered in organic products, the new element was found in a mineral, the scientist decides to give it the name lithium (from the Greek "lithos" for stone).

Soon Arvfedson detected this element in other minerals as well, and the Swedish chemist Berzelius identified it in the mineral waters of Karlsbad and Marienbad. As a matter of fact in our day too the mineral spring waters of Vichy in France enjoy widespread popularity owing precisely to the presence of lithium salts in the water giving it its excellent balneologic properties.

In 1855, the German chemist Bunsen, and independently of him, the British physicist Matheson, succeeded in isolating pure lithium by electrolysis of fused lithium chloride. It turned out to be a soft silvery white metal, barely half the weight of water. In lightness lithium has no rivals among metals: aluminium is five times heavier, iron, 15 and osmium 40 times heavier.

Even at room temperature lithium reacts vigorously with the nitrogen and oxygen of the air. Just try leaving a piece of lithium in a glass vessel with a ground glass plug. It will absorb all the air creating a vacuum in the vessel and atmospheric pressure will force the plug in so tightly that removing it will be a Herculean job. Therefore, storing lithium is a tough problem. While sodium can be successfully hidden in kerosene or gasoline, this will not do for lithium: it will immediately pop to the surface and flare up. To keep the reactive inclinations of lithium in check, lithium sticks are usually kept imbedded in vaseline or paraffin enveloping the sticks and playing the role of a protective coating.

Lithium combines even more readily



with hydrogen. A small amount of it is capable of combining with staggering volumes of this gas: one kilogram of lithium hydride contains 2800 litres of hydrogen! During the Second World War American flyers were provided with lithium hydride pellets as emergency portable hydrogen sources to be used if the plane crashed while flying above water: once in contact with water, the pellets would dissolve instantaneously releasing hydrogen to inflate rescue facilities, such as inflatable boats, life jackets, and signal balloon antennas.

The incredible ability of lithium compounds to absorb water has found extensive use as a means of purifying the air in submarines, respirators on aircraft, and air conditioners.

The first attempts to put lithium to industrial use date back to the beginning of this century. For almost a hundred years up to then, lithium had been mainly used in medicine to treat gout.

During the First World War Germany experienced a desperate need in tin for its industry. The country had no raw material to extract tin from and scientists had to make an urgent search for a replacement. Lithium provided an excellent solution: a lead-lithium alloy (known as Bahnmetal) proved to be a fine antifriction material. Since then technology has constantly found use for lithium alloys, such as alloys with aluminium, beryllium, copper, zinc, and silver. There is a particularly promising future for the alloy with another lightweight metal—magnesium possessing, apart from other good properties, very valuable structural characteristics. A lithium-magnesium alloy containing not more than 50 per cent of magnesium is lighter than water. Some alloys of this compositional range have already been made. But unfortunately they are unstable, oxidizing readily in the air. At present scientists are working on the composition and production technology of an alloy

which would be durable in service. A sample of a lithium-magnesium alloy which does not tarnish with time has already been displayed at the USSR Economic Exhibition in Moscow.

The high reactivity of lithium, its low melting point, and the light weight of its compounds make it an excellent degasser, deoxidizer and modifier in ferrous and nonferrous metallurgy.

In aluminium production lithium is used as a process catalyst. An addition of lithium compounds to the electrolyte bath increases the throughput of an aluminium electrolytic cell, while making it possible to lower the bath temperature and electricity consumption.

In the past the electrolyte of alkaline storage batteries consisted only of sodium hydroxide solutions. The introduction of several grams of lithium hydroxide increases the battery service life three times. The temperature range under which it remains serviceable is also considerably increased: it does not become discharged when the temperature rises to 40°C, nor does it freeze at temperatures down to 20°C below zero. A lithium-free electrolyte cannot withstand such temperatures. The new cell recently developed in Japan has one of its electrodes made of lithium. Its capacity is six to seven times greater than that of its zinc "predecessors".

Some organic lithium compounds (stearate, palmitate and others) retain their physical characteristics within a wide temperature range, which makes it possible to use them in the production of lubricants for machines. The lithium-base lubricant enables cross-country vehicles in the Antarctic to make inland raids to regions where the air temperature is often as low as 60°C below zero. The lithium lubricant is very reliable in passenger cars as well. Owners of the Zhiguli car call it a "permanent lubricant". It is enough to apply it once to some of the car's rubbing parts to last them to the end of their service life.



One of the main characters in the Czechoslovak film *Lemonade Joe*, a parody on Hollywood hits, used to enjoy a "devil's cocktail" which he followed up crunching a few glasses. According to eyewitness accounts, Indian Yogis do not mind partaking of the same "dish" now and then. They will chew a glass and swallow the splinters with such relish as though nothing can be more delicious. And what about you? Have you ever eaten glass? "What nonsense! Certainly not!" the reader is going to say at this point. But he will be mistaken: common glass dissolves in water. Not as readily as, say, sugar, but still it does. The most sensitive analytical balance indicates that we take about one ten-thousandth of a gram of glass with every glass of hot tea. But if salts of lanthanum, zirconium and lithium are added to the glass during manufacture, its solubility will reduce a hundred times. The glass will become resistant even to sulphuric acid.

The role of lithium in glassmaking is not exhausted with lowering the solubility of glass. Lithium-modified glasses exhibit valuable optical properties, excellent stability to heat, high electrical resistivity and low dielectric loss. Lithium, in particular, is used in the glasses from which television picture tubes are manufactured. When ordinary window glass is treated in a melt

of lithium salts, the glass forms a dense protective layer making it twice as strong and stable to elevated temperatures. Slight additions of lithium (0.5 to 1.5 per cent) lower the temperature of the glass melt considerably.

A dew drop has always been taken for a model of transparency. Yet glass transparent like a dew drop no longer satisfies modern technology which needs optical materials letting through not only visible rays of light but also invisible ones, say, ultraviolet. Conventional telescopes are of little use to astronomers straining to catch the radiation of distant galaxies. Lithium fluoride possesses the highest transparency for the ultraviolet rays. Lenses made of lithium fluoride single crystals enable astronomers to penetrate deeper into the secrets of the universe.

Lithium is very valuable for making special glazes, enamels, paints, high-quality porcelain and faience. In the textile industry some lithium compounds are used for whitening and mordanting fabrics and others, for dyeing them.

Lithium salts make tracer bullets and projectiles leave a bright blue-green wake.

The following experiment demonstrates the pyrotechnical abilities of lithium. Try to set fire to a lump of sugar. You will see that it will begin to melt but will not burn. But if the lump is first rubbed with tobacco ashes, it will readily burn with a pretty blue flame. This is to be explained by the fact that tobacco, just as many other plants, contains appreciable amounts of lithium. When tobacco leaves burn some of the lithium compounds remain deposited in the ash, making it possible to show this little chemical trick.

But everything we have discussed so far concerns only secondary, side jobs of lithium. Let us now get down to serious matters.

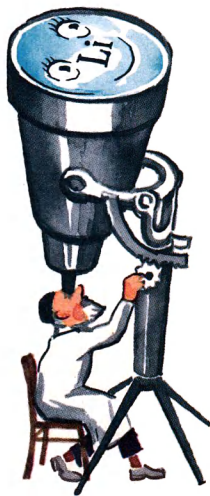
Scientists have found that the nucleus of the isotope lithium-6 can be easily disrupted by neutrons. On absorbing a neu-

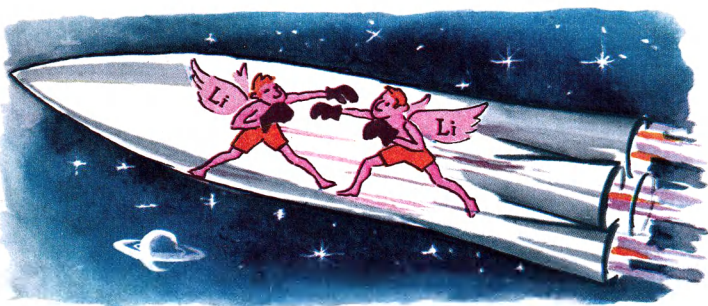
tron, the lithium nucleus becomes unstable and decays to form two new atoms: the light inert gas helium and the rarer super-heavy hydrogen, known as tritium. At very high temperatures tritium atoms and atoms of hydrogen's other heavy isotope, deuterium, combine releasing enormous quantities of energy, the thermonuclear energy.

Thermonuclear reactions are especially vigorous when neutrons bombard the compound formed by the isotope lithium-6 with deuterium, lithium deuteride. It serves as nuclear fuel in lithium reactors, which have some important advantages over uranium ones: lithium is more readily accessible and is cheaper than uranium, it does not form radioactive fission products and the process can be controlled more easily.

The considerable ability of lithium-6 to capture slow neutrons is utilized in the control of the rate of reactions occurring in uranium reactors as well. Thanks to this property, this isotope has found application in radiation protective screens and in nuclear batteries of protracted service life. It is likely that in the near future lithium-6 will be used to absorb slow neutrons in nuclear propelled aircraft and spacecraft. Like other alkali metals, lithium is used as a coolant in nuclear installations. For this purpose the less scarce isotope lithium-7 is quite suitable (natural lithium contains about 93 per cent of it). Lithium-7 cannot serve as a raw material for the production of tritium like its lighter "brother", hence has no significance to thermonuclear technology. But it is quite fit as a coolant. In this role it is made more efficient by its heat capacity and thermal conductivity, the large temperature range of its liquid phase (180° - 1336° Centigrade), its insignificant viscosity and low density.

Lately the rocket and aerospace industry has been making serious claims on lithium. A lot of power is required to overcome the pull of the earth's gravity and break loose





into outer space. The rocket which injected the space vehicle carrying the world's first cosmonaut Yuri Gagarin into orbit had six engines with a total power output of 20 million horsepower! This is equivalent to the output of 20 power plants such as the Dnieper Hydroelectric Power Station.

Naturally the choice of a rocket propellant is a crucial issue. So far kerosene (yes, good old kerosene!) has been considered the most efficient fuel with liquid oxygen as the oxidizer. The calorific value of this propellant combination is 2 300 kcal per kilogram. (For comparison consider that only 1480 kcal of heat are released when one kilogram of nitroglycerin, one of the most powerful chemical explosives known, is exploded.)

Application of metallic fuel has excellent prospects. The theory and technique of using metals as rocket propellants were first developed by the remarkable Soviet scientists Yu. V. Kondratyuk and F. A. Tsander several decades ago. Lithium is one of the metals best suited for this purpose. The combustion of one kilogram of it releases 10 270 kcal! Only beryllium has a greater calorific value. Patents on a solid rocket propellant containing 51-68 per cent of lithium metal have been published in the United States.

It is interesting to note that lithium acts against lithium during the operation of rocket engines. As a fuel component lithium is capable of developing colossal temperatures. Lithium ceramic materials noted for their high heat resistance and refractoriness, (such as "stupalite") are used in coatings for rocket nozzles and combustion chambers to protect them from the destructive effects of the lithium fuel.

In our time industry has at its disposal a large number of synthetic polymeric materials which can be used successfully as substitutes for steel, brass and glass. But production engineers frequently experience difficulties when polymers have to be joined with each other or with other materials. For example, the new fluorocarbon polymer known as teflon is an ideal anticorrosive coating, but until recently it could find no practical application because it could not be adhered to metal.

Recently Soviet scientists worked out an original technology for the nuclear "welding" of polymers to different materials. Small quantities of lithium or boron compounds are applied to the surfaces to be bonded as a sort of "nuclear glue". When these surfaces are exposed to neutron bombardment, nuclear reactions develop releasing considerable energy, so that regions of

the materials on a microscopic scale exhibit temperatures running to hundreds and even thousands of degrees in a very short time (less than a ten-thousand-millionth of a second). But even in those ultrashort intervals the molecules of the interface layers have time to become displaced, mix and sometimes form new chemical bonds between themselves—nuclear welding takes place.

As a rule, elements in the top left corner of the Mendeleev Periodic Table are abundant in nature. But in contrast to most of its neighbours—sodium, potassium, magnesium, calcium and aluminium with which our planet is richly endowed—lithium is a comparatively rare element. It accounts for only 0.0065 per cent of the earth's crust. About 20 minerals containing this valuable element are found in nature, the principal of them being spodumene (triphane). Crystals of this mineral, reminiscent in their shape of railroad cross-ties or tree trunks, sometimes have vast sizes: a crystal over 15 metres long, with a weight measured in tens of tons, was found in South Dakota (USA). Very beautiful emerald-green and pink-violet variants of spodumene, the semiprecious minerals hiddenite and kunzite have been found in American occurrences.

Granitic pegmatites, the reserves of which are practically inexhaustible, can serve as raw materials in lithium production. The estimate is that a cubic kilometre of granite contains 112000 tons of lithium, 30 times more than all the lithium produced today in all the capitalist countries. Apart from lithium, granite deposits contain niobium, tantalum, zirconium, thor-

ium, uranium, neodymium, cesium, cerium, praseodymium and other rare elements. But how can granite be made to share its wealth?

Scientists are now at work searching for methods which, like the storybook words "Open, sesame!", will open the granite storehouses of the earth. They will undoubtedly be successful in their efforts.

Before winding up our story about lithium, let us relate an amusing episode from the life of the American physicist Robert Wood in which lithium had a very important part to play. In 1891 Robert Wood, a Harvard graduate and the future celebrated scientist, arrived in Baltimore to study chemistry under the well-known Professor Remsen. He stayed at a boarding house near the University where he soon heard from other students there that the landlady often cooked their morning stew from dinner leftovers she collected from the plates the day before. But how was that to be proved?

Wood was famous for his ability to find original and simple solutions to problems. He was true to himself this time too. When a stake was served for dinner one day he left untouched several big hunks of meat which he had sprinkled with lithium chloride, an absolutely harmless substance looking and tasting much like common table salt. Next day the students collected a few pieces of meat which had been served them for breakfast and examined them through a spectroscope. The red line of the spectrum produced by lithium put the dot over the i. The thrifty landlady was exposed. Years later Wood recalled his "criminal investigation" with pleasure.

SPACE-AGE METAL



Fairy-tales coming true.—Emerald mines of Queen Cleopatra.—A Roman Emperor's hobby.—“It is green, pure, gay and tender ...”—The treasure of Mexican tombs.—The secret of the Incas.—“A green morning and blood-red night”.—Gilda is looking for beryllium.—A “wounded” exhibit.—Vauquelin's sensational statement.—A “violator of the peace”.—A cruel accusation.—The “verdict” repealed.—Out into space!—An incredible order.—No explosion is expected.—An alliance of the lightest.—An important discovery.—Neutrons slow down their pace.—Record-breaking velocity.—An atomic “needle”.

"Beryllium is one of the most remarkable elements of tremendous theoretical and practical significance.

"Mastery of the air and daring flights of aircraft and balloons are impossible without light metals; and we already foresee that beryllium will arrive to help the current aircraft metals, aluminium and magnesium.

"And then our aircraft will fly with a speed of thousands of kilometres per hour.

"The future belongs to beryllium!

"Geochemists, start looking for new beryllium deposits. Chemists, learn to separate this light metal from its companion, aluminium. Technologists, it is for you to make the lightest alloys that will not sink in water, but will be hard as steel, elastic as rubber, strong as platinum, and eternal as a semiprecious stone.

"Perhaps now these words seem like a fairy-tale. But how many fairy-tales have become reality before our eyes, a part of our daily life, and we forget that only 20 years ago our radio and our talking pictures sounded like a fantastic fairy-tale."

So wrote Academician A. E. Fersman,

the outstanding Soviet scientist who was able to see the true value of beryllium as early as several decades back.

Yes, beryllium is a metal of the future. But at the same time there are few elements in the Periodic Table whose history extends as far into the past as that of beryllium.

... More than 2000 years ago slaves were mining lovely crystals of green stone—emeralds—in the famous mines of Queen Cleopatra in the lifeless desert of Nubia. Caravans of camels shipped the emeralds to the shores of the Red Sea from where they found their way to the palaces of the sovereigns of Europe, and Middle and Far East—Byzantine emperors, Persian shahs, Chinese mandarins and Indian rajahs.

Throughout the ages emeralds have fascinated man with their gorgeous lustre, purity of colour and beauty of iridescence (from a deep green, almost dark, to a sparkling, blinding green). The Roman Emperor Nero liked to watch gladiator fights through a large crystal of emerald.

"Emeralds are green, pure, gay and tender like the spring grass", wrote the well-known Russian writer A. Kuprin.



With the discovery of America a new page was written in the history of the green stone. In the graves and temples of Mexico, Peru, and Colombia the Spaniards discovered great numbers of large dark-green emeralds. This fantastic treasure was plundered within a few years. For a long time though, they had failed to find the place where the magnificent gem had been mined. It was only in the middle of the 16th century that the conquerors of America were able to uncover the secret of the Incas and find the emerald mines of Colombia.

The Colombia emerald of exceeding beauty ruled the jewelry market until the 19th century. In 1831 Maxim Kozhevnikov, a Ural charcoal burner, found the first Russian emerald while gathering windfallen branches along the tiny river Tokovaya. The large bright-green emeralds of the Urals rapidly gained recognition among jewellers throughout the world.

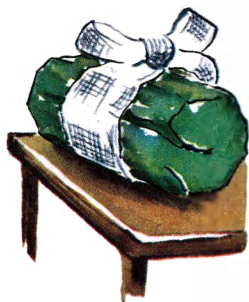
The emerald is one of many beryllium minerals. The bluish-green, seawater-coloured aquamarine and the rose-coloured vorobyevite, the wine-yellow heliodor and the yellowish-green, snake-coloured beryl, phenakite of the colour of the purest water and the delicate blue euclase, the transpar-

ent green chrysoberyl and its astonishing variety alexandrite which is deep green by day and crimson in artificial light ("green morning and blood-red night", as the Russian writer N. Leskov described it)—these are only some, but perhaps, the most esteemed members of the family of beryllium gems.

Lately it has been reported in newspapers more and more often that geologists are assisted by ... dogs in their search for minerals. The ability of our four-legged friends to find something by smell has been known since long ago, but what about their "geological talent"? What minerals can the shaggy "oreseekers" discover? This is what the initiator of the new trend in geological prospecting G.A. Vasilyev, Doctor of Science (Biology), has to say about it: "We are helped in this question by the collection of the Mineralogical Museum of the USSR Academy of Sciences. Our experiment with beryllium metal was particularly successful. The dog Gilda sniffed this mineral and then was offered a whole collection of minerals among which to look for it. Gilda chose emerald, aquamarine, vorobyevite, phenakite and bertrandite, that is, only the minerals containing beryllium. Then we again placed the beryllium-containing minerals among other specimens and after the dog had been through finding them once more, we again asked her to look. Gilda made a round of the museum then put her paws on the case in which a huge emerald was exhibited and barked."

Of all the beryllium-containing minerals only beryl is of industrial value. Gigantic crystals of beryl occur naturally. They may weigh tens, hundreds or even thousands of kilograms. One of the biggest crystals known is nearly 9 metres long.

A crystal one and a half metres long is on display at the Leningrad Mining Museum. During the 1942 blockade a shell went through the museum roof and exploded in the main hall. The crystal was damaged severely by the splinters and it



could hardly be expected that it would ever be on display again. But a few years ago it was restored through painstaking efforts of the restorers. At present two rusty shell splinters imbedded in the thick plastic glass plate on which the crystal rests and a note telling about its history are the only things that remind us of the "surgery" which the crystal had to go through.

It is not surprising that the beautiful beryllium gems have always attracted not only lovers of precious stones but also chemists.

In the 18th century, when the element which is now placed in the Periodic Table under the number 4 was still unknown to science, many scientists attempted to analyze beryl, however no one could detect the new metal contained in it. It looked like the element was hiding behind the back of aluminium and its compounds—its properties were strikingly similar to those of aluminium. But there were also differences. And the first who was able to note them was the French chemist Nicolas Louis Vauquelin. On the 26th of Pluiose of the fourth year of the French revolutionary calendar (i.e. 15 February, 1789) at a conference of the French Academy, Vauquelin gave a sensational report that beryl and emerald contained a new "earth" different in its properties from alumina or aluminium oxide. Vauquelin proposed to name the discovered element "glucinium" owing to the sweetish taste of its salts (in Greek "glykys" means sweet). Now this name is retained only in France, while in other countries the name "beryllium" proposed by the well-known chemists M. Klaproth and A. Ekeberg is used.

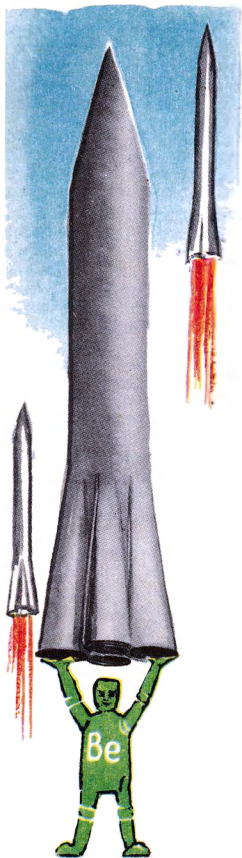
The similarity of beryllium and aluminium caused quite a bit of trouble to the author of the periodic law Dmitry Mendeleev. The fact is that precisely because of this similarity, in the middle of the 19th century beryllium was considered to be

a trivalent metal with an atomic weight of 13.5 and, consequently, should have occupied in the table a place between carbon and nitrogen. This introduced obvious confusion in the regular change of properties of elements and brought under doubt the correctness of the periodic law. Mendeleev, convinced that he was right, asserted that the atomic weight of beryllium had been incorrectly determined, that the element was not trivalent but divalent and possessed the properties of magnesium. On the basis of this he placed beryllium in the second group, having corrected its atomic weight to 9. Soon the Swedish chemists L. Nilson and O. Petersson who had been convinced of the trivalency of beryllium, had to confirm Mendeleev's view: their careful investigations showed that the atomic weight of beryllium was 9.1. Thus one of the fundamental chemical laws triumphed owing to beryllium, "violin of the peace" in the Periodic Table.

The fate of beryllium in many respects is similar to the fate of its fellow metals. It was isolated in a free form in 1928 by F. Wohler and A. Bussy, but only seven decades later was the French scientist P. Lebeau able to obtain pure metallic beryllium by electrolysis of fused salts. It is no wonder that even at the beginning of this century chemical handbooks categorically accused beryllium of being a "sponger", asserting that "it has no practical use".

The rapid development of science and technology which has marked the 20th century compelled chemists to reexamine this obviously unwarranted "verdict". A study of pure beryllium has demonstrated that it possesses many valuable properties.

Being one of the lightest metals, beryllium at the same time is remarkably strong, stronger than structural steels. Moreover, it has an appreciably higher melting point than magnesium and aluminium. This fortunate combination of properties makes beryllium one of the



basic aircraft materials today. Aircraft parts made of beryllium are one and a half times lighter than those made of aluminium.

Excellent thermal conductivity, high heat capacity, and heat resistance make it possible to use beryllium and its compounds in space engineering as a heat-protective material. According to American press reports, the nose cone and floor of the cabin of the *Friendship-7* spacecraft, on which John Glenn made his orbital flight, were manufactured from beryllium.

Parts made from beryllium are capable of maintaining high precision and stability of dimensions and are used in gyroscopes, instruments of the orientation and stabilization systems installed on rockets, spacecraft and artificial earth satellites.

There is yet another property of beryllium which makes it promising in space engineering: while burning it releases colossal amounts of heat—15 000 kcal per kilogram. Thus, it may well be used in highly efficient propellants for flights to the Moon and other celestial bodies.

Alloys of beryllium with copper—beryllium bronzes—are widely used in aviation for the manufacture of many elements requiring high strength, good resistance to fatigue and corrosion, retention of elasticity in a wide temperature range and high electrical and thermal conductivities. It has been calculated that in a modern heavy aeroplane more than 1 000 parts are made of these alloys. Thanks to its elastic properties, beryllium bronze serves as an excellent spring material. Springs made from it are practically unaffected by fatigue, being capable of withstanding up to 20 000 000 load cycles.

Incidentally, a curious episode from the history of the Second World War is connected with springs. Germany's industry was cut off from the main sources of beryllium raw material. The world extraction of this valuable strategic metal was almost wholly in the hands of the USA. The Ger-

mans resorted to cunning. They decided to use neutral Switzerland to smuggle beryllium bronze: an order was sent to American companies from Swiss "watchmakers" for such a quantity of beryllium bronze that it would be sufficient to supply the entire world with watch springs for 500 years to come. True, the ruse was discovered, but nevertheless springs made of beryllium bronze appeared from time to time in the latest models of rapid-firing aircraft machine guns delivered to Hitler's army.

(Fatigue is one of the "occupational diseases" of many metals and alloys which gradually disintegrate, unable to withstand variable loads.) The addition to steel of even a small quantity of beryllium makes this disease vanish as if by a wave of a wand. While automobile springs made from ordinary carbon steel break after 800-850 000 impacts, they can withstand 14 million impacts without a sign of fatigue after "vitamin Be" has been introduced to the steel from which they are made.

Unlike steel, beryllium bronze does not spark when hit on stone or metal. That is why it is indispensable for making tools used in explosion-hazard work in mines, at powder factories and oil dumps.

Beryllium strongly affects the properties of magnesium. The addition of only 0.01 per cent of beryllium prevents magnesium alloys from igniting during casting (i.e. at a temperature of something like 700° C). It also drastically reduces the corrosive properties of alloys both in the air and in water.

Alloys of beryllium with lithium are evidently to play an important role in the future. It is very likely that the union of these two lightest metals will result in the creation of alloys that will not sink in water.

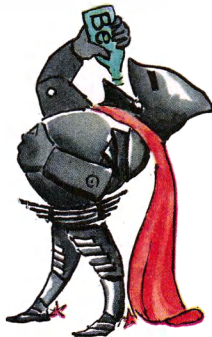
Beryllium is also an excellent steel deoxidizer, although it is, unfortunately, still too expensive (one kilogram of beryllium costs some 150 dollars in the United States

at present, which is much more than the price of tantalum, niobium, or zirconium, not to mention the comparatively inexpensive silver).

Metallurgists have found yet another important use for beryllium. Saturation of the surface of steel parts with this metal (beryllization) substantially increases their hardness, strength and wear resistance.

X-ray technicians are also favourably disposed to beryllium, since it transmits X-rays better than any other metal stable in the air. Now the "windows" for X-ray tubes are made from it throughout the world. The transparency of such "windows" is by a factor of 17 higher than that of aluminium previously used for this purpose.

Beryllium has played a remarkable role in the development of the atomic structure theory. While bombarding beryllium with alpha-particles, the German physicists V. Bothe and G. Becker discovered the so-called "beryllium radiation", which was very weak but possessed a very appreciable penetrating ability: it went through a layer of lead several centimetres thick. In 1932 the British scientist Sir James Chadwick





established the nature of this radiation as being a flux of electrically neutral particles, each with a mass approximately that of the proton. The new particles were given the name "neutrons".

The absence of an electric charge enables the neutrons easily to become imbedded in the nuclei of other elements. Owing to this property, the neutron has become a most effective "shell" of the atomic artillery. Today neutron guns are extensively used to trigger off nuclear reactions.

The study of the atomic structure of beryllium has shown that it is characterized by a small neutron-capture cross-section and a large scattering factor. Beryllium scatters neutrons, changes their direction and slows down their speed to values where chain reactions proceed more effectively. Beryllium is considered to be the best

of all the hard materials in slowing down the neutrons. It is also an excellent neutron reflector returning neutrons to the active zone of the reactor and preventing their leakage. It likewise possesses a high radiation resistance, a property it retains even at very high temperatures. All these remarkable properties make beryllium an essential element in atomic engineering.

The "sound transmitting" ability of beryllium is doubtlessly of interest to science. The velocity of sound is 330 metres per second in the air and 145 metres per second in water. In beryllium it is the record-breaking 12 500 metres per second.

Beryllium oxide too has many valuable properties. The high refractoriness (melting point 2570°C), appreciable chemical resistance and high thermal conductivity explain the use of this material to line induction furnaces and to manufacture crucibles for melting metals and alloys. Thus, crucibles of beryllium oxide are used in a vacuum for melting beryllium, which absolutely does not react with them. This oxide is the basic material for fuel-element jackets of atomic reactors.

The heat-insulating properties of beryllium will probably be used in the study of the deep-lying layers of our planet. A project has been initiated to take a mantle sounding at a depth of 32 kilometres by means of the so-called "atomic needle" which is a miniature atomic reactor in a beryllium oxide casing.

The prophetic words of the remarkable scientist and dreamer A. E. Fersman have come true. Beryllium has needed quite little time to justify the hopes placed on it. From a little-known rare element it has become one of the most important metals of the 20th century.

A FIGHTER AGAINST FATIGUE



The alchemists' headache.—“The truth is in water”.—Instead of the “philosopher's stone”.—There were no fireworks. In the flame of a match.—Hydrophobia.—In the lower layers of the earth's mantle.—“Mountain leather”.—Which method is better?—Neptune can relax.—Each brings its share.—Under difficult conditions.—In the world of metallurgy.—It will not be necessary to wait.—“One, two, three! Now!”—There are more important things to do.—In an egg's shell.—Eat peaches.—Threat of infarction.—“Will it be a son or a daughter?”—Should we imitate cows?—A new refractory.—Grinard's contribution.—The best role is still ahead.

The search for the notorious "philosopher's stone" was the biggest headache of "researchers" in medieval alchemic laboratories. The "stone" was to help them obtain gold from baser metals.

The search proceeded in various directions. Some asserted that lead, heated up to the point when it would release the "red lion" (i.e. up to melting point) and then boiled in tart grape alcohol, was the best raw material for the production of "the philosopher's stone", others thought that it was animal urine, while still others insisted that the truth was in water.

At the end of the 18th century a British alchemist, who was evidently a representative of the third group, boiled some mineral spring water near the town of Epsom, but instead of the "philosopher's stone", obtained a salt with a bitter taste and a laxative effect. A few years afterwards it was found that when this salt interacted with the "permanent alkali" (as soda and potash were called in those times), it formed a white friable and light powder which was exactly the same as the one produced by roasting a mineral discovered near the town of Magnesian in

Greece. Because of this similarity Epsom salt was named white magnesia.

In 1808 Sir Humphry Davy, the well-known English scientist, analyzed white magnesia and obtained a new element which he named magnesium. The celebrations on the occasion of the discovery were not accompanied by fireworks because people then did not know that the new-born element possessed excellent pyrotechnical properties.

Magnesium is a very light silvery-white metal having only a fifth of the weight of copper and a 4.5th of the weight of iron. Even the "winged" aluminium is one and a half times heavier than magnesium. Its melting point is comparatively low, just 650°C , but it is quite difficult to melt magnesium under ordinary circumstances: heated in the air to a temperature of 550°C it bursts into a flare and burns up immediately with a blinding bright flame (this property is widely used in pyrotechnics). To ignite magnesium it is enough to hold a burning match to it, while in the atmosphere of chlorine it will flare up even at room temperature. While burning, magnesium emits large quantities of ultraviolet rays and heat: four grams of this "fuel" is sufficient to bring a glass of ice-cold water to a boil.

In the open air magnesium soon becomes dull, as oxidation film forms on its surface fast. This film, however, is a reliable protection against further oxidation.

Magnesium is very aggressive, easily depriving most elements of oxygen and chlorine. But while it effectively resists the action of some acids, soda, caustic alkalis, gasoline, kerosene and mineral oils, it is powerless against seawater and dissolves in it. It shows practically no reaction with cold water, but rapidly forces hydrogen out of hot water.

The earth's crust is rich in magnesium (more than 2.3 per cent). Only six of its "colleagues" in the Mendeleyev Table are found in nature in greater quantities.



Scientists believe that the lower layers of the earth's mantle contain particularly large amounts of this element. Magnesium is found in the composition of nearly 200 known minerals. One of them is quite extraordinary: it can be folded as a handkerchief, used as wrapping paper, or torn to shreds.

Some 20 years ago a unique specimen of this mineral was found in the Soviet Far East. Miners of a polymetal ore mine discovered a small cave and in it, hanging from the ceiling, there was something that looked like a greyish-white "curtain" doubled in the middle. It was about a metre and a half long and a metre wide and to the touch felt like suede, soft and elastic. The lightness of the "fabric" was fantastic.

The unusual find was sent to Moscow. A chemical analysis showed that it consisted mainly of aluminosilicate of magnesium and was in fact the mineral palygorskite of the asbestos group which was first discovered by Academician Fersman in the twenties of this century in the Palygorsk deposit in the Ural Mountains. For its unusual properties this mineral is often referred to as "mountain leather". The "leather" found in the Far East and now on display in the Mineralogical Museum of the USSR Academy of Sciences is remarkable in that it is the biggest in size ever discovered in the world.

Magnesite, dolomite and carnallite are the principal industrially important raw materials for magnesium production.

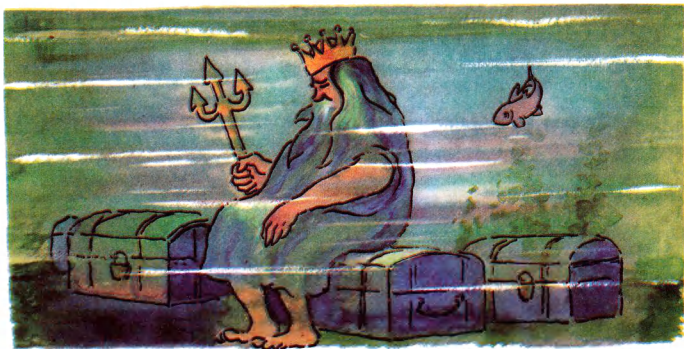
Two processes are employed to produce magnesium: the electrothermal and electrolytic processes. The first is when magnesium oxide is reduced by any reducing agent—carbon, aluminium, etc. This process is quite simple and has been in increasingly wider use lately. But still the second, electrolytic, process remains the main one in magnesium production today. It consists in electrolysis of fused magnesium salts, mainly chlorides, yielding

a very pure metal which contains more than 99.99 per cent of magnesium.

But not only the earth's mantle is rich in this metal. The "blue chests" of the seas and oceans are a storehouse of practically inexhaustible and constantly replenished reserves of it. A mere cubic metre of seawater contains nearly 4 kilograms of magnesium. In all, over $6 \cdot 10^{16}$ tons of this metal is dissolved in the waters of the seas and oceans. Even people far removed from mathematics will not find it hard to perceive the magnitude of this figure. But still, here is an example to illustrate: since the beginning of its chronology, mankind has lived a little more than 60 thousand million seconds ($6 \cdot 10^{10}$). Even if mankind had begun to use seawater to produce magnesium from the very first days of our era, it would have to turn out one million tons of this metal every second to have exhausted its reserves by now.

But Neptune should not worry for his wealth: even during the Second World War when magnesium production from seawater was at its peak it did not exceed 80 000 tons a year (not a second!). The method by which magnesium is extracted from water is quite simple. Seawater is mixed in great tanks with lime milk prepared from sea shells. This mixture, called "magnesium milk", is then turned into magnesium chloride. After that magnesium is separated from chlorine by electrolysis. Not long ago the Japanese firm Kurita Kogio designed a plant for the comprehensive utilization of seawater. According to estimates, the processing of four million litres of sea water will yield 108 tons of table salt, 2.2 tons of Glauber salt, 16.7 tons of chlorine and 15.9 tons of magnesium. Besides that, the plant will turn out three million litres of drinking water and a large amount of brine for the production of caustic soda.

The water of salt lakes can also serve as a source of magnesium if it contains magnesium chloride (known as natural brine).



In the Soviet Union such "storehouses" of magnesium are found in the Crimea (the lakes Saki and Sasyk-Ivash), in the Volga area (Lake Elton) and in other regions.

So much for magnesium production. But what about the utilization of this element and its compounds?

Its light weight could make magnesium an excellent structural material. But unfortunately, pure magnesium is soft and wobbly. Therefore, engineers have to make do with alloys of magnesium with other metals. Its alloys with aluminium, zinc and manganese are in especially extensive use. Each of the components of this partnership plays its own role in improving the general properties of this metal: aluminium and zinc build up its strength and manganese increases its corrosion resistance. And magnesium? Magnesium makes the alloys light. Parts made of magnesium alloys are 20 to 30 per cent lighter than aluminium parts and 50 to 75 per cent lighter than cast-iron or steel parts. Such alloys are "offered jobs" more and more often in the automobile and textile industries and in printing.

Magnesium alloys have many other

partners that increase their refractoriness and ductility and decrease their oxidizability. Among them are lithium, beryllium, calcium, cerium, cadmium and titanium. But there are also some enemies: iron, silicon and nickel impair the mechanical properties of magnesium alloys and reduce their corrosion resistance.

Magnesium alloys are widely used in the aircraft industry. Back in 1935 Soviet aircraft designers built the *Sergo Ordzhonikidze* plane which contained almost 80 per cent of magnesium alloys. The plane passed all tests without a hitch and was in service for a long time under rigorous conditions.

Magnesium alloys are indispensable in the manufacture of rockets, nuclear reactors, engine parts, petroleum and oil tanks, railway car frames, buses, passenger cars, wheels, oil pumps, rock hammers, pneumatic drills, still and movie cameras and binoculars. And this list of instruments, parts, and subassemblies is far from complete.

Magnesium is also important to metallurgy where it is used as a reducing agent in the production of a number of metals,

including vanadium, chromium, titanium and zirconium. Introduced as a modifier into molten iron, magnesium improves its structural and mechanical properties. Castings made of magnesium-modified cast-iron have successfully replaced steel forgings. Apart from that, magnesium helps to deoxidize steel and alloys (it reduces the content of oxygen, which is in this case a harmful impurity).

It is known that common electron valves begin to function normally only after they heat up to 800° C. Every time a radio or TV set is switched on some time passes before there is any sound or sight. To remove this shortcoming Polish scientists have suggested that the cathodes should be coated with magnesium oxide. The new valves begin to work as soon as the TV or radio set is turned on.

The ability of magnesium (in the form of powder, wire or ribbon) to burn with a dazzling white flame is made a wide use of in military technology for the manufacture of signal and other flares, tracer bullets and shells and incendiary bombs. Until recently the magnesium flare was indispensable in photography. "One, two, three! Now!" and a magnesium powder flare would light up the faces of those who wished their images to go down to posterity. But not any more: powerful electric lamps have forced magnesium out of this job.

Not that it hurts magnesium in any way: it has many and much more important things to do. It takes part in the great work of storing solar energy. It is a component of chlorophyll, the great wizard which absorbs solar energy and turns carbon dioxide and water into complex organic substances (sugar, starch, etc.) essential for the nutrition of man and animals. The process of formation of organic substances—photosynthesis (from the Greek "photos" meaning "light")—is accompanied by expiration of oxygen from the leaves. There would be no life without chlorophyll and there would be no chloro-



phyl without magnesium, for it makes up two per cent of it. Is this much? Judge for yourself. The total amount of magnesium in the chlorophyll of plants alone is something like 100 000 million tons. Apart from the plants magnesium is present in the composition of practically all living organisms, human being included. For example, if one's weight is 60 kilograms, about 25 grams of it is magnesium.

Several years ago researchers at the University of Minnesota in the USA found that the more magnesium an egg shell contained the stronger it was. This meant that by changing the feed of laying hens it would be possible to make the egg shell harder. The meaning of this discovery to agriculture is illustrated by the following figures: the annual loss due to breakage in Minnesota alone is over one million dollars.

Magnesium finds an extensive application in medicine. We have already mentioned Epsom salts (magnesium salt of sulphuric acid or magnesium sulphate) which is an effective laxative. Pure magnesium oxide (roasted magnesium) is used to treat high gastric acidity, heartburn and acid poisoning. Magnesium peroxide is a well-



known disinfecting agent used for gastric disorders.

According to statistics, spasms of the blood vessels are far less common in inhabitants of northerly regions. It is general knowledge that intravenous and intramuscular injections of certain solutions of magnesium salts ease spasms and convulsions. Some fruits and vegetables (particularly apricots, pears and cauliflower) are a good source of magnesium helping to store the necessary quantity of this element in the organism. In regions where the diet is richer in magnesium, say in Asia, atherosclerosis and other heart diseases are less common than in Europe or the United States.

In Hungary it has been established experimentally that a deficiency of magnesium in the organism enhances predisposition to myocardial infarctions. One group of dogs was given feed which was rich in magnesium salts and the other was kept on a magnesium-deficient ration. By the end of the experiment the second group had suffered myocardial infarctions.

The incidence of heart disorders is much higher among nervous, easily excitable persons. This is explained by the fact that at

the moment of excitation the magnesium of the organism "burns up".

In the opinion of French biologists, magnesium is to help medicine to fight fatigue, the scourge of our time. Their experiments have demonstrated that the blood of tired people contains less magnesium than that of people who are physically fit, and it is a fact that even the slightest deviation of the normal "magnesium curve" produces a harmful effect.

It was also established by French biologists not long ago that some elements influence the sex of progeny. It appears that an excess of potassium in the mother's food results in her offspring being mostly male, but if her food is rich in calcium and magnesium her offspring will predominantly be female. Probably the time is not far off when physicians will be prescribing special menus for mothers to guarantee the birth of a boy or girl "on order". But it will first have to be found if these elements have this effect on the human organism: the observation just described has so far applied to ... cows.

Medicine is not the only field where magnesium compounds are in extensive use. For example, magnesium oxide is used in rubber industry and also in the production of cement and refractory brick. Recently a Canadian firm developed a process for manufacturing a new refractory material (newcon), stable to the effect of slags, characterized by great strength and low porosity. High-purity magnesium compound is the basic component of the new refractory. Magnesium peroxide is used for bleaching fabrics (novozon). Magnesium sulphate finds application in the textile and paper industries as a mordant in dyeing. The water solution of magnesium chloride is the basis for the production of magnesium cement, xylolith and other synthetic materials. Magnesium carbonate is used for the making of heat-insulating materials.

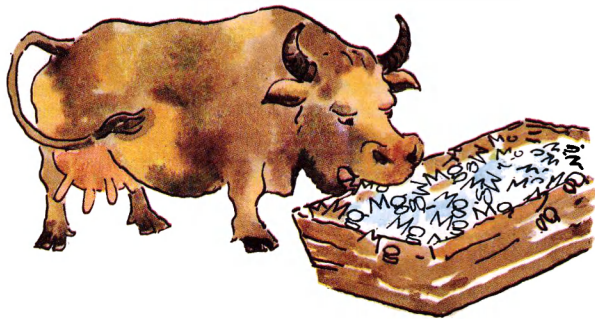
Organic chemistry is yet another vast field for the activities of magnesium. In

powder form magnesium is used to dehydrate important organic substances, such as alcohol and aniline. A significant role belongs to organomagnesium compounds (in them the atom of magnesium is bonded directly to the atom of carbon). These substances, particularly alkylmagnesium halides (Grignard reagent), with halogens (chlorine, bromine or iodine) included in their composition, are widely used in synthetic chemistry. The importance of these compounds is proved by the fact that the French chemist Victor Grignard was awarded the 1912 Nobel Prize for the discovery of alkylmagnesium halides and for related work in developing the synthesis of organic compounds.

Thus it is clear that the role of magnesium in nature and in the national economy is vast. Still it is probably too early to say that this element has accomplished everything that it could. For example, not long ago magnesium alloys, from which parts of the rock-sampling automatic drilling rig on board the *Luna-24* space probe were made, "visited" the Moon where they "took part" in the "mining" of

lunar rock. The rig had to meet strict demands. First it had to be light: on a lengthy journey every excess kilogram of load means additional fuel expenditure; second, the parts absolutely had to be strong: no sense sending them on such an important trip, unless there was certainty that they would not let down at a crucial moment. And obviously the working moments on the Moon could well turn out really crucial.

The designers of the rock-sampling automatic drilling rig settled for the super-light and strong titanium and magnesium alloys. Before sending the drill on its space journey scientists subjected it to a severe test on earth, making it drill different kinds of rock, including very hard mountain rock. The test was first conducted under normal climatic conditions and then in a big pressure-chamber where deep vacuum was created or the temperature was raised or lowered to imitate lunar temperatures of up to plus 110°C in the daytime and minus 120°C at night. The tests were successful, as was the subsequent flight of the automatic station which brought lunar rock to earth.



SILVER FROM CLAY



Tiberius removes the “danger”.—Experiments drag on.—The monarch’s splendid camisol.—Sensation at the Paris Fair.—A banquet in the Emperor’s Palace.—Napoleon III’s daring project.—A new dress for the cuirassiers.—“Aluminium everywhere...”—Mendeleyev is given a present.—A complaint from the population of La Glacière.—A Chinese tomb mystery.—An engineer’s foresight.—In search of “companions”.—Wilm cannot believe his eyes.—The “flying bookcases” disappear from stage.—A museum piece.—The exhibit changes its passport.—Echo-I reflects radio signals.—Aluminaut submerges into the abyss.—The Russian Troika.—Half a century later.—A magic fabric.—Blanket kept in a cigarette-case.—On Mars and the Moon.—Aluminium from... garbage.

The ancient historian Pliny the Elder relates a remarkable event that took place almost two millennia ago. One day a stranger came to see the Roman Emperor Tiberius and made him a present of a cup made from a metal which was shiny like silver but very light. The man explained that he had obtained the new metal from clay. Apparently gratitude was a feeling that seldom burdened Tiberius and he was a short-sighted ruler. Fearing that the new metal with its magnificent properties might devalue the gold and silver treasury he ordered the inventor to be beheaded and his workshop destroyed, so that no one would ever get the idea of producing the "dangerous" metal.

It is hard to say whether the incident really took place or was invented. At any rate "the danger" was removed, and, unfortunately, for a long time to come. It was only in the 16th century, that is something like one and a half thousand years later, that a new page was written into the history of aluminium by the talented German doctor and natural historian Philippus Aurelius Theophrastus Paracelsus Bombastus von Hohenheim.

Studying various substances and minerals, including alum, Paracelsus established that they were "a salt of some alum earth", one of the components of which was an oxide of an unknown metal, subsequently called alumina.

The mineral that interested Paracelsus had been known from ancient times. According to the Greek historian Herodotus who lived in the 5th century B.C., ancient people used a mineral rock they called "alumen" (meaning "binding") as a fixing agent in dyeing. It was the same alum that the German scientist studied.

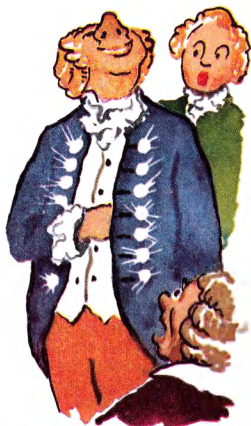
The first mention of alum production in Russia dates back to the 8-9th centuries. There it was also used in dyeing and in the manufacture of morocco leather. In the Middle Ages there were several alum plants in Europe.

In 1754 the German chemist Marggraf was able to isolate "alum earth" mentioned by Paracelsus 200 years previously. But another several decades had passed before the Englishman Davy attempted to obtain the metal concealed in the alum. In 1807 he discovered sodium and potassium by electrolysis but he was not able to decompose alumina by the same process. Similar attempts were undertaken several years afterwards by the Swedish chemist Berzelius, but in vain. Still scientists decided to give a name to the evasive metal: first Berzelius called it "aluminium" and then Davy changed it into "aluminium".

The first who managed to obtain metallic aluminium like that craftsman of ancient Rome was the Danish scientist Oersted. In 1825 he published an article in a chemical journal stating that as a result of his experiments he succeeded in producing a piece of metal that "looks somewhat like tin in colour and lustre". But since it was not a very well-known journal, Oersted's report passed practically unnoticed in the scientific circles. Busy with research into electromagnetism, Oersted himself did not attach particular importance to his discovery.

Two years later Oersted was visited in Copenhagen by Wohler, a young but already well-known German chemist. Oersted told him that he was not going to continue his experiments in the production of aluminium. When Wohler returned to Germany, he immediately began working on the problem of aluminium production which had greatly intrigued him. Already at the end of 1827 he published a paper describing his method of producing the new metal. True, Wohler's process enabled him to extract aluminium in the form of grains that were not larger than a pin-head, but the scientist persisted in his experiments until he was able to produce aluminium in the form of compact mass. That took him 18 years.

(By that time the new metal had won



popularity, but since it was made in minute quantities, it cost more than gold and was very hard to get.

Small wonder, therefore, that when a European monarch bought a camisole with aluminium buttons for his personal use, he began to look down on all other rulers who could not afford such luxury. The latter could only envy the lucky owner of the rare buttons quietly and wait for better times.

To their great joy, they did not have to wait long: already in 1855 "silver from clay" was put on display at the World's fair in Paris causing a sensation. Those were aluminium plates and ingots produced by the French scientist and industrialist Saint Claire Deville.

The following events preceded the appearance of the exhibits. France was then ruled by Emperor Napoleon III "the little nephew of a great uncle", as he was called. He loved to show off and one day he gave a banquet at which the members of the royal family and the more illustrious

guests were given the honour of eating with aluminium spoons and forks. The less honourable ones had to do with the common (at the Emperor's table) gold and silver sets. It hurt them of course and food stuck in their throats, but there was nothing anyone could do about it because even the Emperor could not provide every guest with the precious aluminium.

Soon Napoleon devised a daring project which would bring him fame and glory, but even more important, would make other sovereigns turn green with envy: he decided to equip his army with aluminium armour. He provided Saint Claire Deville with considerable means so that a way of producing aluminium in greater quantities could be developed. Taking Wohler's principle as a basis, he was able to develop a new production method but the metal he made was still very expensive.

That was why the French army was not lucky enough to try on new armour, but the Emperor took care of his personal guards who began to parade new aluminium cuirasses.

It was at about this time that "Deville's silver" was put on display at the World's Fair. Probably the organizers did refer aluminium to commercial metals, but that did not make it more easily available. True, foremost people of the time even then realized that the buttons and cuirasses were only a minor episode in the history of aluminium. When the Russian writer Nikolai Chernyshevsky saw aluminium for the first time he exclaimed in admiration: "A great future is destined for this metal! Friends, you see before you the metal of socialism." In his novel *What is to be Done?* (1863) there is the following passage: "... How light is the architecture of this inner house, how small the piers between the windows,—and the windows themselves are huge, wide and tall, reaching to the ceiling... But what are these floors and ceilings made of? And the frames of these doors and windows?

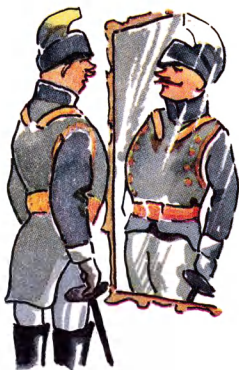
Silver? Platinum? Oh, I know now, Sasha showed me a plank made from this material and it was as light as glass. Now they wear such ear-rings and brooches, yes, Sasha said that sooner or later aluminium will replace wood and maybe even stone. But how rich it all looks! Aluminium everywhere... Here in this hall half of the floor is bare, and you can see that it is also made from aluminium..."

When these prophetic words were written aluminium was still pretty much a jeweller's metal. It is an interesting fact that even in 1889 when Mendeleyev was in London he was given a valuable gift as a token of recognition of his outstanding achievements in chemistry: scales made of gold and aluminium.

Meanwhile Deville in France had started feverish activity on the construction of what was to be the world's first aluminium plant at La Glacière. But the production involved emission of such amounts of poisonous fumes into the atmosphere of La Glacière that the local inhabitants, who treasured their health too much to sacrifice it to technological progress, lodged a complaint with the government. The plant had first to be moved to Nanterre in the environs of Paris, and subsequently, to the south of the country.

By that time many scientists had realized that all Deville's efforts notwithstanding, his method had no future. Chemists in different countries continued the search. In 1865 the well-known Russian chemist Beketov suggested an interesting method which was soon introduced in the aluminium plants in France (at Rouen) and in Germany (at Gmelingen near Bremen).

The year 1886 became a landmark in the history of aluminium. It was then that the American student Hall and the French engineer Heroult developed, independently of each other, an electrolytical method of aluminium production. The idea was not new: back in 1854 the German chemist



Bunsen suggested that aluminium could be obtained by electrolysis of its salts. But more than thirty years had passed before his idea found practical application. Since this method required large amounts of electricity, Europe's first plant for the electrolytical production of aluminium was built in Neuhausen (Switzerland) near the Rhine waterfalls which were a cheap source of power.

Today, almost a hundred years later, the production of aluminium other than by electrolysis is still inconceivable. This is a fact that makes scientists rack their brains over one mysterious circumstance: recently a spectral analysis of an ornament from the tomb of Chou-Chu, the well-known military leader in 3rd-century China, revealed that 85 per cent of the alloy from which it was made was aluminium. It was so incredible that the analysis had to be repeated several times, and every time the unbiased spectre indubitably showed that the ancient masters had indeed made the ornament from aluminium. But how was it possible in the 3rd century? The only knowledge of electricity



that man had then was lightning and it is doubtful that he could put it to any practical use. The only thing to suppose is that in those remote times people knew some other method of producing aluminium, which was, unfortunately, lost over the ages.

At the end of the eighties of the last century the "biography" of aluminium had another important page added to it. The Austrian chemist Bayer, then working in Russia, developed and applied successfully an original process of producing alumina, the principal raw material for aluminium production, in factory conditions. The Bayer process was soon recognized throughout the world and is still valued at present.

Those years the production of aluminium went up sharply and the price of this metal which was considered precious shortly before, dropped considerably. While in 1854 the cost of one kilogram of

aluminium was 1200 roubles, it went down to one rouble towards the end of the century. It goes without saying that jewellers lost all interest in aluminium which had immediately attracted the world of industry, then standing on the threshold of great events: engineering was making rapid headway and the motor industry was just starting out, but even more important, aviation, in which aluminium was to play a crucial role, was preparing to make its first steps.

In 1893 in his book *Aluminium and its Metallurgy* published in Moscow, the Russian engineer N. Zhukov wrote: "Aluminium is destined to play an outstanding role in engineering and replace many if not all, conventional metals..." There were good reasons for Zhukov's statement; by that time the wonderful properties of "silver from clay" had already become known. Aluminium is one of the lightest metals—it is more than three times lighter than copper, and 2.9 times lighter than iron. In its thermal and electrical conductivity it is inferior only to silver, gold, and copper. Under ordinary conditions the metal is sufficiently stable chemically. Its plasticity makes it possible to flatten it into foil a mere 3 microns thick, or to draw it into a wire not thicker than a spider's web (1000 metres of it weigh 27 grams and can be folded in a match-box). Only its strength characteristics could be better. Aluminium's lack of strength was what prompted scientists to seek ways of making it stronger without impairing its good properties.

It has long been established that the strength of many alloys is often much greater than that of the pure metals making them up. This is why metallurgists started looking for appropriate "companions" for aluminium which could make it stronger. Success was soon to come, and as happened many times in the history of science, chance played all but

a crucial role in it. But, back to the beginning.

One day (that was in early 20th century) the German chemist Wilm prepared an aluminium-based alloy with copper, magnesium and manganese. The alloy was stronger than aluminium but Wilm felt that it could be made still stronger by hardening it. He heated several samples of the alloy to something like 600°C and then plunged them in water. The strength of the alloy did increase, but since the results of the experiment with different samples were not identical, Wilm began to doubt the accuracy of the instrument he used and the measurements.

He spent several days checking the instrument. The samples, which he had ignored for the time being were lying on the table, and by the time the instrument was once more ready for use, they had become much harder than before. Wilm went on with his experiments and could not believe his own eyes: the instrument showed that the strength of the samples had almost doubled.

The scientist repeated his experiments again and again and every time saw that for 5 to 7 days after quenching his alloy was continuing to gain in strength. Thus he stumbled upon an amazing phenomenon—the natural ageing of aluminium alloys after quenching.

Wilm himself did not know what was happening to the metal during the ageing, but he found by experiment the optimal composition of the alloy and worked out the heat-treatment conditions, patented his method and soon sold it to a German firm which produced the first batch of the new alloy in 1911 and gave it the name "duraluminium" (after the town of Dueren where the industrial production of the alloy was started). Subsequently the alloy began to be called "duralumin".

In 1919 the first planes were made of duralumin. Since then aluminium has firmly been associated with the destiny of



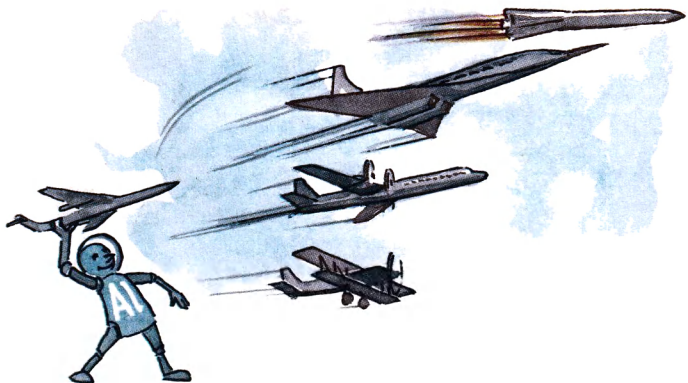
aviation. Its reputation of a "winged metal" was well-earned: it had soon turned the primitive "flying bookcases" into gigantic airliners. But duralumin was still scarce in those years and many light planes were still being made of wood.

In the Soviet Union it was only the Kolchugino nonferrous metals processing plant that produced some quantities of aluminium alloys. One of them was "kolchugaluminium", an alloy resembling duralumin in composition and some properties. The urgent issue was to develop large-scale aluminium production.

Early in 1929, experiments to produce aluminium were conducted at the Krasny Vyborzhets plant in Leningrad. They were directed by P. P. Fedotyev, an outstanding researcher who added many remarkable pages to the history of the "winged metal".

On March 27, 1929, the experiments resulted in the production of the first 8 kilograms of the metal. Fedotyev wrote afterwards: "This moment can be considered the birth of the production of aluminium in the USSR on the basis of the Volkhov River electricity and wholly from materials of domestic manufacture."

It was pointed out in the Leningrad newspapers then that the "first ingot of



aluminium which is a museum treasure must be preserved as a monument to one of the most outstanding achievements of Soviet technology". The samples produced at the Krasny Vyborzhets and some aluminium articles were presented, on behalf of the working people of Leningrad, to the 5th USSR Congress of Soviets.

The first successful experiments made it possible to begin the construction of the Volkhov and Dnieper aluminium plants. The first of them went into operation in 1932 and the second a year later.

During the same period considerable reserves of aluminium ore were discovered in the Ural Mountains. The discovery had an interesting prehistory. In 1932, a young geologist, N. A. Karzhavin, became interested in an exhibit on display at a Ural mine which was believed to be iron ore with a low iron content. The geologist was struck by the ore's similarity with bauxite, a mountain clay rock rich in aluminium. Having analysed the mineral, Karzhavin found that the "impoverished iron ore" was an excellent aluminium raw

material. A search for the mineral was started in the area where the ore had originally come from. Success was not long in coming.

On the basis of the newly-discovered deposit the Ural Aluminium Plant was built to be followed a few years later (already during the Second World War) by the Bogoslovsky Plant which started production on the historical Victory Day of May 9, 1945.

At present there are many plants in the Soviet Union engaged in the production of the "winged metal", but the demand for it still grows. It is, naturally, still mainly consumed by aviation, being the first among metals used in the construction of aircraft and missiles. It accounts for two-thirds to three-fourths of the dry weight of an airliner and from one-twentieth to one-half of the dry weight of a missile.

The shell of the first Soviet artificial earth satellite was made from aluminium alloys. The shells of the American *Vanguard* and *Titan* missiles, which were used to orbit the first American satellites and later

spaceships, were also made from aluminium alloys. Aluminium is also used for various parts of space apparatus—brackets, fastenings, chassis, casings, and tool cases.

The *Echo-1* radio-signal reflecting satellite, launched in the United States in the 1960s, was a huge sphere (about 30 metres in diameter) made from aluminium-vapour-coated polyester film. Despite its impressive dimensions the apparatus weighed no more than 62 kilograms.

Foil made from the purest aluminium served as a fluorescent screen mounted on one of the satellites for the study of charged particles emitted by the Sun. When the American astronauts Neil Armstrong and Edwin Aldrin landed on the Moon, they spread a sheet of similar foil on its surface and let it there for two hours to study the effect of the gases emitted by the Sun. Getting ready for their journey back to earth, the astronauts packed the foil and the samples of lunar rock they had collected into special aluminium boxes.

Aluminium is as indispensable in the study of the ocean depths as it is in the space conquest. Several years ago American engineers built an oceanographic submarine, *Aluminaut*, which can submerge to a depth of 4 600 metres. The new super-deep ship is not built of steel as would be usual, but of aluminium.

France has built a 315-metre-long ocean-going vessel with a displacement of over 50 000 tons and carrying 2 000 passengers whose hull, piping, boats and even furniture are made of aluminium.

The sphere of application of aluminium is being constantly expanded. A list of articles manufactured from aluminium, which was drawn up in the United States after the war, contained something like 2 000 items.

Electrical engineering is one of the principal consumers of aluminium, using it for high-voltage transmission lines, motor

and transformer windings, cable, caps, condensers, etc.

It is also welcome in transportation. At present work is under way in the Soviet Union to build a railroad super-express with an aluminium body. It will bear the poetic name *Russian Troika* and resemble the fuselage of a modern airliner. Its speed will be that of a TU jet at take-off. The experimental car has already been tested: subjected to a pressure of 200 tons, violent vibration and other "exertions", the metal remained intact. The day is not far off when the *Russian Troika* will make its first race through the vast expanses of this country.

Aluminium is highly resistant to corrosion. It owes this property to the very thin film (0.0001 millimetre!) which forms on its surface and is like armour protecting it from oxygen. But for this protective film aluminium would flare up even in the air and burn with a blinding flame. The "armour" makes it possible for aluminium parts to serve for decades even in the chemical industry which is such a "health hazard" for metals employed in it.

Scientists have established another interesting fact: aluminium does not destroy vitamins. That is why equipment for butter production, sugar refining, confectionery and brewing industries is made from it. Aluminium has a very strong position in construction. As far back as 1890 it was used for the first time in history in the construction of a house in an American town. Fifty years later all of its aluminium parts were in a fine state. The first aluminium roof built in 1897 is still in no need of repair.

The grand Palace of Congresses inside the Moscow Kremlin is made of aluminium and glass. The Soviet pavilion built from glass and aluminium at the World's Fair in Brussels in 1958 was so majestic that the Belgian newspapers called it a "Palace of Socialism". The wonderful

light-weight metal is now to be encountered everywhere—in the construction of bridges and buildings, hydraulic structures and hangars.

Aluminium is important to metallurgy as an agent removing oxygen from steel. Aluminium grit is the main component used in aluminothermal processes for obtaining many alloys.

One may come across aluminium even in stamp collections: in 1955 a postal stamp made of aluminium foil 0.009 millimetre thick was released in Hungary. Afterwards such stamps were published in other countries as well.

Aluminium fabric (or, more exactly, fabric in a super-thin aluminium coating) has been developed. It can be used for warming up or for cooling, as the case may be: curtains made from it will let in light but keep out the heat if hung with the metal facing the outside on a hot summer day. In winter the metal surface of the curtains should face the inside of the room and it will keep the warmth in. A raincoat made from this fabric will protect one both from heat and cold: worn with the metal lining on the outside it will make a good shelter from the scorching sun, and when reversed, it will keep one warm. Czechoslovak industry has begun the production of aluminium-coated blankets which are equally good in warm and cold apartments. Furthermore, they weigh 55 grams and are neatly folded into a container not larger than a cigarette-case.

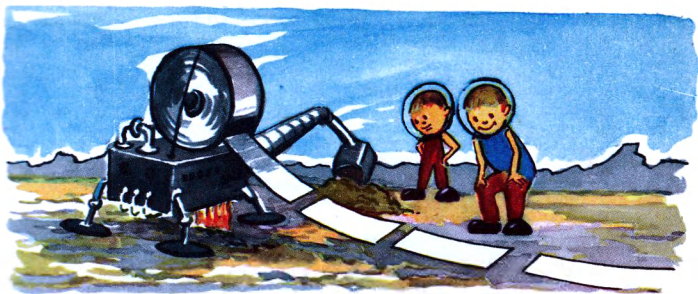
Geologists, tourists, and fishermen, in other words, all those who spend much of their time in the open air will treasure the jackets and tents made from the new fabric. In hot climates "aluminium" caps, hats, robes, and umbrellas are going to be in great demand. Aluminium-coated overalls will make the work of a steel smelter "cooler", and it will also be a great help to the firemen.

Lately scientists and engineers have given much attention to the development of fundamentally new materials—foam metals. The method of manufacturing foam aluminium, the first of that remarkable metal family of the future, has already been worked out. The new material is incredibly light: one cubic centimetre of foam aluminium weighs only 0.19 gram. Cork which has always been considered a standard of lightness is incapable of competing with foam aluminium—it is 25 to 30 per cent heavier. Foam aluminium is to be followed by foam beryllium, foam titanium and many other remarkable materials.

This is how H. G. Wells, the famous science fiction writer, described at the break of this century the machine which the Martians in his novel *War of the Worlds* used to make aluminium: "From sunset to the appearance of the stars this clever machine manufactured at least one hundred strips of aluminium directly from clay."

An American scientist suggested an interesting hypothesis back in the years when people had only a visual knowledge of the Moon. According to it, up to 200 tons of pure aluminium were concentrated on every hectare of the Moon's surface. His guess was that the Moon was something like a gigantic natural plant in which the so-called solar wind (the flux of protons coming from the Sun) turns the ores of iron, magnesium, and aluminium into pure metals. So far the hypothesis has not been confirmed, although it is true that the content of aluminium oxide, as shown by analyses, in the specimens of lunar rock brought to earth by the American astronauts and by the Soviet automatic stations is nearly 15 per cent which is rather much.

It seems then that the "aluminium problem" has been solved on Mars and the Moon. But what about it here on earth? It



can be said that all is well, here too, even though we haven't got the machines that the Martians had, and lumps of aluminium are not found lying about on the surface of our planet. Still earthlings have no cause for complaint: nature has taken care to provide them with adequate amounts of this wonderful metal. As far as its content in the earth's crust is concerned, aluminium is inferior only to oxygen and silicon and far exceeds all the other metals.

Nature is indeed wealthy but man must learn to be a thrifty manager of its wealth. Engineers have designed quite a number of installations, and some of them are already in operation, serving to extract valuable

components from the waste going to the city garbage heaps. They are fitted out, among other things, with electromagnetic devices to "extract" aluminium from garbage. But it is a fact that the magnetic field has no effect on aluminium. Then how is it possible with its help to obtain the metal? It appears that if an alternating current is passed through an object made from aluminium by moving it in an electric field, the metal is magnetized for some time. This is when it "falls pray" to the magnets.

In short, it seems that aluminium is in good supply. It is for scientists and engineers now to develop new technology and methods to produce the "winged metal" and find new uses for it.

SON OF THE EARTH



A rocket that will never leave the Moscow sky.—“Ever changed your last name?”—In honour of Gaea’s sons.—A titanic task.—Mistake after mistake.—A new step.—Hunter succeeds.—A fly in the ointment.—Acting walk-on parts.—Irony is unwarranted.—Release from captivity.—“Black Bird”.—Specialists forecast.—Paradox?—A ridiculous point of view.—No harm from corrosion.—A thousand years from now.—In the abyss of the ocean.—A monument in Geneva.—The fault can be cured.—And you call this rare?!—A mine in the Mare Tranquillitatis.—In the clutches of oxygen.—Severe trials.—Mysteries unravelled.

At dawn on August 18, 1964, a rocket was launched in Prospekt Mira in Moscow. It was not destined to reach the Moon or Venus but its fate was to be no less glamorous: it was a silvery obelisk of a soaring rocket frozen for ever in the Moscow sky, which was to immortalize the feat of the Soviet spaceman who blazed the trail in space.

The authors of the project had been unable for a long time to decide on the facing material for this magnificent monument. First they designed it in glass, then in plastic and then in stainless steel. Finally all three projects were vetoed by the authors themselves. Their lengthy experiments ended in the choice of polished titanium sheets.

But why was it that titanium and not some other metal was entrusted with the honourable mission of telling future generations of the feat performed by our contemporaries?

It is for good reason that titanium is called a perpetual material. Before going into its properties though, let us learn something about its history.

If titanium had to fill out a form, then in the column "Change of name if any" it would have to mention that indeed it had been called "menaccin" up to 1795. That was the name given to it in 1791 by the English chemist and mineralogist, William Gregor, who had discovered it in the mineral menaccanite. But apparently the element did not like the name and at the first opportunity (which turned up in 1795 when the German chemist Martin Klaproth rediscovered it, this time in the mineral rutile) changed it to the beautiful and meaningful "titanium" derived from "Titan" as the sons of Gaea (Earth) were called.

Two years later it was found that Gregor and Klaproth had discovered one and the same element for which the proud name "titanium" was finally adopted.

To discover an element does not mean

to have it in pure form. Both Gregor and Klaproth had succeeded in obtaining a chemical compound of titanium with oxygen, titanium dioxide, a white crystalline powder. The separation of titanium from its compounds proved to be a really titanic task. Many noted chemists tried to accomplish it in the past century but failed.

It seemed at one time that the English chemist Wollaston was close to success. Studying some crystals found in slags at Merthyr-Tydfil plant in 1823, he arrived at the conclusion that they were nothing other than pure titanium. Thirty-three years later the German chemist Wohler showed that those crystals were a compound of titanium with nitrogen and carbon, and not free titanium as Wollaston had mistakenly assumed.

For many years had scientists believed that the first metallic titanium was obtained in 1825 by the well-known Swedish chemist and mineralogist Berzelius when he reduced fluortitanate of potassium by metallic sodium. But comparing what we know of titanium today with the product obtained by Berzelius, we can assert that the President of the Swedish Academy of Sciences was mistaken in assuming he had pure titanium, since pure titanium readily dissolves in hydrofluoric acid while Berzelius's "titanium" successfully resisted it.

It was only in 1875 that the Russian scientist D. K. Kirillov was able to obtain metallic titanium. Kirillov published the results of his work in a brochure entitled *Research into Titanium*. But there was no one in tsarist Russia to become interested in that remarkable work and it had never been acknowledged.

In 1887 Berzelius's compatriots Nilson and Pettersson produced a substance containing about 95 per cent of titanium by reducing titanium tetrachloride by metallic sodium in an airtight steel cylinder.



The next step on the way to produce pure titanium was made in 1895 by the French chemist Henri Moissan who reduced titanium dioxide by hydrogen in an arc furnace and then subjected the metal he had thus received to double refining. The result was titanium containing only two per cent of impurities.

Finally, in 1910 the American chemist Hunter improved the method of Nilson and Pettersson and was able to obtain several grams of comparatively pure titanium. That event caused wide repercussions in many countries. Naturally, therefore, many even today ascribe priority in obtaining pure titanium not to Kirillov but to Hunter.

At any rate pure titanium was finally produced. But it was only by stretching the point considerably that this metal could be accepted as pure, for it still contained several tenths of a per cent of impurities. Only several tenths, but they were like a fly in the ointment. The impurities made titanium fragile and brittle and unsuitable for machining. It earned a bad fame for being a useless, good-for-nothing metal.

It goes without saying that with such characteristics titanium could not dream of any serious job and had to be content with "walk-on parts".

In 1908 Rose and Bartran in the United States and Farup in Norway suggested that white pigments should be made not from lead compounds but from titanium dioxide. Titanium white was a much better pigment than the old lead white. Furthermore, it was not poisonous (the hazard of lead white), as titanium dioxide is harmless to the human organism. There was a case registered in medical history when a person swallowed almost 500 grams of titanium dioxide and survived.

Gradually titanium dioxide began to be used in dyeing leather and fabrics, in the making of glass, porcelain and enamels, as well as of imitation gems.

Another titanium compound—titanium tetrachloride—was also given something to do. This compound was obtained for the first time by the French chemist Dumas back in 1826. The ability of titanium tetrachloride to form dense smoke screens was extensively used during the First World War. In peacetime this substance is used to fumigate plants during spring frosts.

But, as we shall yet see, titanium had every right to claim much more serious and exciting jobs.

In 1925, the Dutch scientists van Arkel and de Boer decomposed titanium tetrachloride on a heated tungsten wire and obtained high-purity titanium. And then it became clear that Hunter's assertion concerning the brittleness of titanium could not stand up to criticism: the metal produced by van Arkel and de Boer was highly plastic, could be forged like iron and rolled into sheets, strip, wire and even the thinnest foil.

Now the magnificent name that the element had been given no longer seemed ironic. Titanium had a wide road into technology open before it.

As though in gratitude for its release from the grip of impurities, titanium began to reveal stunning properties to scientists. It was found, for example, that while

weighing only half as much as iron, titanium was stronger than many steels.

In its strength titanium has no competitors among industrial metals. Even the versatile aluminium has been forced to give up some of its jobs in favour of titanium which is only one and a half times heavier, but also six times stronger. What is particularly important is that titanium retains its strength even at high temperatures (up to 500°C, and with the addition of alloying elements, up to 650°C), whereas the strength of many aluminium alloys is drastically reduced even at a temperature of 300°C.

Titanium is a very hard metal: twelve times harder than aluminium, and four times harder than iron and copper. The higher the yield point of a metal the better the resistance to operational loads of the machine parts made from it, and the longer they retain their shape and dimensions. The yield point of titanium is 18 times higher than that of aluminium and 2.5 times higher than that of iron.

Small wonder then that when aircraft designers had to decide on what metal could be trusted to overcome the sound barrier, they chose titanium. Recently a Western newspaper reported that American engineers have built a supersonic jet (*Black Bird*) which is capable of making more than 3 200 kilometres an hour. Its body is made of titanium. Titanium has also been used for the construction of the principal exposed parts of the world's first Soviet supersonic passenger airliner TU-144, including the engine nacelle, the ailerons and the rudders.

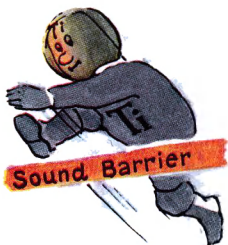
Titanium is used more and more often to manufacture many other aircraft units and parts—from the engine to bolts and nuts. Talking of bolts, American specialists say that the replacement of steel bolts in the engine with titanium ones in one type of a fighter plane reduces the weight of the engine by almost 100 kilograms. Since

each of these saved kilograms reduces the weight of the plane by ten kilograms (since the fuselage becomes lighter), the total gain in weight economy comes to one ton. One can easily imagine what it will mean to reduce the weight of a plane by a whole ton when the reduction by only one kilogram results in an economy of up to 400 roubles a year. Specialists maintain that in the coming few years the proportion of parts made from titanium and titanium-base alloys on planes moving at speeds two or three times faster than the speed of sound is to come to between 60 and 90 per cent.

Space-age technology will not be able to do without titanium either. Titanium tanks are excellent for storing liquid oxygen and hydrogen: at super-low temperatures titanium is not disintegrated like most metals but, on the contrary, gains in strength.

Very likely titanium will serve as the principal structural material for installations assembled directly in space. The experiments carried out in 1969 by the Soviet cosmonauts Georgy Shonin and Valery Kubasov showed that titanium





readily yields to welding and cutting in space vacuum.

It is not only the designers of spacecraft equipment that have a great respect for titanium. One foreign firm uses it for the manufacture of bicycle frames. A titanium frame weighs a little over a kilogram and the weight of the whole bicycle is less than seven kilograms.

Chemists have also become interested in titanium. An experiment carried out at a chemical plant produced the following results: three pumps made respectively from cast iron, stainless steel and titanium to pump aggressive liquids lasted: the first for three days, the second, for 10 days and the third one remained intact after half a year of non-stop operation.

Despite the fact that titanium is still very expensive, its replacement for cheaper materials has proved in many cases to be more economical. For example, the reaction vessel in a chemical installation made from stainless steel costs 150 roubles and the one made from a titanium alloy, 600 roubles. But the stainless steel vessel remains in working order for 6 months and the titanium one, for 10 years. If the expenses involved in replacing the steel

reaction vessels and the unavoidable idling of the equipment are considered, it becomes obvious, however paradoxical it may sound, that the expensive titanium is cheaper than the cheap steel.

Several years ago a London exhibition devoted to the uses of titanium in industry had on display a wide assortment of titanium equipment for chemical plants, including titanium nozzles, which, after working for more than two months in an atmosphere of hot gases, and among them sulphur dioxide, remained in working order. Nozzles made of stainless steel began to crumble after several hours of work.

Titanium is very good for the manufacture of components working in the aggressive media of chlorine, sulphuric or nitric acid, etc. Some plants have even installed huge (120 metres high) ventilating pipes made from titanium. True, a pipe like that is a bit expensive, but it will stand for a good hundred years without any need of repairs and will make up for the expense many times over.

Titanium is extensively used in the making of hard alloys for cutting tools. Even a very thin titanium-carbide coating considerably improves cutting characteristics of the tools and the quality of machined surfaces.

Surgical instruments made from titanium alloys enjoy well-earned fame. The Soviet doctor Yuri Senkevich who took part in the expedition of Thor Heyerdahl, the well-known Norwegian explorer, on board the *Ra* papyrus boat, carried with him a set of titanium surgical instruments.

Recently scientists have created a magic alloy of titanium with nickel—nitinol—which possesses a mysterious ability to “remember” its past, that is, to take its old form after deformation and machining (a more detailed story in the chapter “The Copper Devil” devoted to nickel).

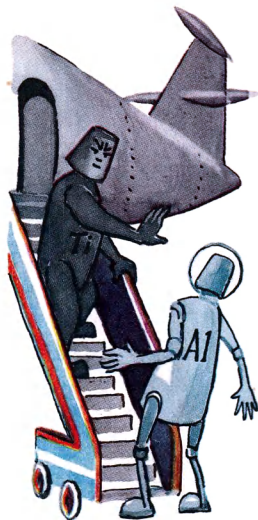
Even at the beginning of the 20th

century metallurgists overwhelmingly believed that titanium was one of the most harmful contaminants of iron. Many years had passed before the absurdity of this view was proved with the result that metallurgy today is a principal consumer of titanium.

There are hundreds of grades of steel and alloys that contain definite quantities of titanium. Added to stainless steel, it prevents intercrystalline corrosion. In heat-resistant alloys with a high chromium content, titanium reduces the size of the grain, making the structure uniform and finely crystalline. In other heat-resistant alloys titanium serves as a strengthening agent.

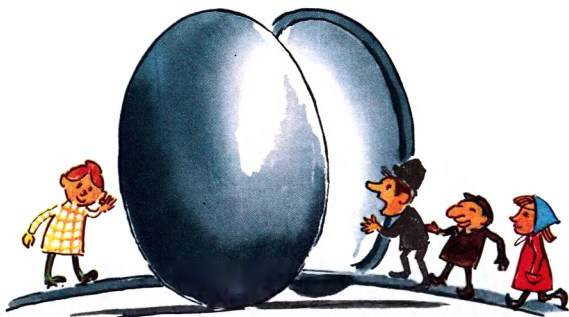
The intensive reaction of titanium with oxygen (we shall yet discuss this point) makes it possible to use titanium to deoxidize steel, that is, to remove oxygen from it. In its deoxidizing ability titanium is something like ten times superior to silicon, which is one of the main deoxidizers. Titanium plays the same role with respect to nitrogen. Degassing of steel improves its mechanical properties and enhances its corrosion resistance.

Titanium's resistance to corrosion, the worst enemy of metals, is truly remarkable. A titanium plate submerged in seawater for ten years did not show even a trace of rust (nothing would have been left of it if it had been made of iron). But we should not even pause to discuss such a trifle as ten years: calculations show that if this experiment had begun a thousand years ago, say about the time Russia was being converted to Christianity, then by today corrosion in the titanium plate would have gone not deeper than 0.02 millimetre. It is for good reason, therefore, that designers of underwater craft have as great a liking for titanium as do aircraft designers and chemists. The American General Electric have been working on a project of inhabited underwater stations submersible to depths of up to 3700



metres in which titanium alloys are to play a major role.

The high resistance to corrosion explains why the builders of the obelisk commemorating the conquest of outer space chose precisely this metal as a facing material. Recently titanium came in handy in the case of yet another monumental structure. At the UNESCO-sponsored contest of projects for a monument to commemorate the centenary of the International Union of Electrocommunication, the project by Soviet architects won the first prize. It was to be erected in the Palace of the Nations square in Geneva and was to consist of two concrete shells, 10.5 metres high, faced with polished titanium plates. A person passing between the shells along a specially laid walk would



hear his voice, the sound of his steps and the noise of the city, and would see his image in the centres of the two circles retreating into infinity.

Nonmagnetism is another important property of titanium, which is important to many fields of technology. Titanium has a high electrical resistivity. If the electrical conductivity of silver is to be conventionally taken for 100, then the conductivity of copper will be 94, aluminium 55, iron and mercury 2 and of titanium 0.3. This is why titanium is widely used in electrical engineering.

Thus, titanium is a lucky possessor of many valuable properties. Why then has it not been applied as widely in industry as, say, steel or aluminium?

The high price has been a brake of a sort on the utilization of titanium. Strictly speaking, this "fault" is not an inborn one but is explained by the extreme difficulties involved in separating the metal from its ores. If the relative cost of titanium in a concentrate is taken for 1, then after a lengthy and complicated technological process whereby titanium becomes a ready product—a thin sheet—the cost will have risen 500 to 600 times. But this situation is not hopeless: titanium

production is being constantly improved and the time is not far off when it will be as cheap as aluminium, a metal which even at the end of the last century was a competitor of precious metals. It is not a matter of such a distant future when customers at stores will be buying table sets and kitchen utensils made of titanium and its alloys. Titanium wares will join mass-produced goods.

Until very recently and absolutely groundlessly, titanium was believed to be a rare metal (even now it is sometimes regarded as such). In fact, however, only a few elements have a wider distribution in nature. The amount of titanium in the earth's crust is several times that of many metals, including copper, zinc, lead, gold, silver, platinum, chromium, tungsten, mercury, molybdenum, bismuth, antimony, nickel and tin taken together.

But in a sense the term "rare" indeed has some relation to titanium: it is a rare mountain rock that does not contain this element (of the 800 kinds of rock explored, 784 contained titanium!)

There are about 70 minerals which have titanium as a component in the form of dioxide or salts of titanous acid. The more important of them are ilmenite (formerly

known as menaccanite), rutile, perovskite, and sphene. The "family" of titanium minerals is constantly joined by new members. Only recently a hitherto unknown titanium mineral (more correctly a grain of it weighing a tenth of a gram) was found in the Lovozerskaya tundra (on the Kola Peninsula) which was given the name "natisite" (based on the names of the elements it contains: sodium, titanium, and silicon). Rich deposits of titanium ores are to be found in the USSR (the Ural Mountains, Siberia, the Ukraine, Altai, and the Khibiny Mountains), the United States, India, Norway, Canada, Australia and other countries. In all, there are 150 known substantial titanium ore occurrences and placers in the world.

Even before the flights of the American *Apollo* ships and the Soviet *Luna* space probes which returned samples of lunar rock to earth, some scientists suggested that it must contain considerable quantities of titanium oxide. Experiments have now proved them to be correct. Who knows, probably, newspapers of a non-too-distant future will report the opening of what will be the first lunar titanium mine somewhere in the region of Mare Tranquillitatis or Oceanus Procellarum.

The crew of the Soviet *Soyuz-13* spaceship, Pyotr Klimuk and Valentin Lebedev, brought interesting data to earth, including an ultraviolet spectrogram of one planetary nebula, which has always excited particular interest of astronomers. A typical nebula is a gaseous formation with a hot star in the middle. Since nebulae are situated at great distances from the earth, our information of them is extremely fragmentary. Over all the years that they have been under study, only 17 chemical elements have been discovered in them, and notably, none during the last 25 years. But now the instruments on board the *Soyuz-13* have irrefutably established the presence of another two elements—aluminium and titanium in the nebula's composition.

Thus, neither our planet nor its closest neighbour, nor other celestial bodies have cause to complain about the absence of titanium. But it has to be extracted from the ore first and processed into a state in which it can be used by modern technology. And this is not a simple proposition at all.

The point is that the union of titanium and oxygen (and it is precisely in this combination that titanium is usually found in nature) is among the most stable ones



known to chemistry. Neither electric current, nor high temperatures can tear titanium out of the clutches of oxygen. Therefore, scientists have been forced to look for round-about ways of obtaining free titanium.

In 1940 the American scientist Kroll succeeded in developing a process of industrial titanium production whereby titanium dioxide was converted into titanium tetrachloride by means of chlorine and carbon, after which it was much easier to deal with chlorine which would have replaced oxygen. Then magnesium or some other element was introduced. The reaction of titanium tetrachloride with magnesium produced a "sponge" consisting of titanium, magnesium and magnesium chloride. To obtain pure, dense titanium the "sponge" was smelted in vacuum or in an inert gas atmosphere (to protect the metal from atmospheric nitrogen and oxygen).

Another way of obtaining metallic titanium is the sodium-thermal process which, in principle, is little different from the magnesium-thermal one. At present the iodide process proposed by van Arkel and de Boer, the scientists we have already mentioned, is used to produce titanium of special purity. This process yields commercially pure titanium by transforming its chloride into iodide which is then vacuum-sublimated. Reacting with heated (up to 1400°C) titanium wire, iodide vapour disintegrates and pure titanium settles on the wire. This process being very

costly, it is not yet employed industrially, and the titanium obtained in this way is mainly used for laboratory research.

Thus, the properties of titanium largely depend on its purity, therefore, the development of processes whereby high-purity titanium can be mass-produced is a crucial problem facing industry. For it is a fact that only infinitesimal amounts (several thousandths of one per cent) of the truly great natural titanium reserves are transformed into metal at present. Despite the rapid growth of production capacities, the demand for this wonderful metal is clearly ahead of the supply. It is for good reason that for a long time the American government forbade manufacturers to sell rolled titanium to non-military enterprises.

Specialized research institutes, the number of which is constantly growing, are today working on the problem of how to make titanium cheaper. It is noteworthy that when a new institute of light metals was being inaugurated in Cleveland (USA) several years ago, the traditional ribbon stretched across the entrance was made from ... titanium. In order to cut it the Mayor of Cleveland had to use a gas burner and wear protective glasses.

In our day titanium holds the attention of thousands of scientists, and specimens of this metal are "tortured" in numerous laboratories: torn to pieces, bent, cooked in acids and alkalis, heated red, cooled to super-low temperatures, tested by monstrous loads, high-frequency currents, and by ultrasound. And it reveals its secrets.

“VITAMIN V”



A find on the scene of a crash. — An idea becomes reality. — The Goddess does not answer the knock. — Nils Sefstrom's luck. — Del Rio's mistake is repeated by Wohler. — The second birth of vanadium. — "I was an ass ..." — Henry Roscoe's successful experiments. — 50 thousand roubles for one kilogram! — Ore from Venus. — The secret of indefatigable steel. — A field gun in the sky. — Serving offensive and defensive purposes. — Steel workers turned diplomats. — A rainbow of ink. — The pigs are pleased. — Marine collectors. — Plantations on the seabed. — A message from the past.

"But for vanadium, there would have been no automobile," said the motor king Henry Ford. In 1905 Henry Ford was present at a big motor racing event and as often happens at such races, there was a collision. After a while Ford went up to the scene of the accident and picked up a fragment of one of the crashed cars. It was a French car and the fragment had belonged to its valve spindle. There seemed nothing special about it but Ford, who was extremely sharp on such matters, was struck by its lightness and considerable hardness. The laboratory to which he had sent the fragment to be analyzed reported that the unusual steel contained vanadium.

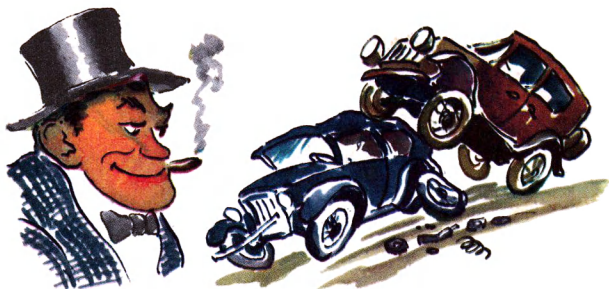
Ford was completely carried away by the idea of introducing such steel in the automobile industry on a large scale. And for good reason: should his idea prove feasible, the automobile would become much lighter, large amounts of metal would be saved and cars would become much cheaper. It would mean that the number of buyers would go up dramatically, raising his own profits. And Ford got down to business. He had to overcome formidable difficulties before he was able to carry out his plan. When the French Department of Commerce and Industry tested some parts of the new Ford car several years after the

race that was destined to play such an unexpected and crucial role in the history of the motor industry, it was established that the American steel was far superior to the French in all its characteristics.

What is vanadium, the metal that has accomplished a virtual revolution in the motor industry? This is how the well-known Swedish chemist Berzelius describes the history of its discovery:

"Long, long ago there lived in the far North Vanadis, a beautiful goddess beloved by all. One day when she was reclining comfortably in her chambers she heard a knock at her door. She thought to herself: 'Let him knock once more.' But the knock was not repeated and she heard someone go away. The Goddess was curious: 'Who could that modest and diffident visitor be?' She opened a window and looked out into the street. That was a certain Wohler, whom she saw hurriedly leave her courtyard.

"A few days later she again heard knocking at her door but this time the knocking went on and on until she got up and opened the door. She was confronted by the handsome Nils Sefstrom. Very soon they fell in love with each other and had a son whom they named Vanadium. And that was the name of the new metal which



was discovered by the Swedish physicist and chemist Nils Sefstrom in 1831."

There is one inaccuracy in the story. The first who knocked at the door of Goddess Vanadis was not the German chemist Friedrich Wohler, but the distinguished Mexican chemist and mineralogist Andres Manuel del Rio. Long before Wohler, in 1801, while studying the brown lead ores of Mexico, del Rio discovered that they contained a hitherto unknown metal. Its compounds came in varied colours and the scientist gave it the name of "panchrominum", that is, "omnicoloured", and subsequently changed it into "erytronium", which means "red".

But del Rio could not prove his discovery scientifically. Furthermore, in 1802 he arrived at the conclusion that the element was chromium, the element which had been discovered not long before. Several years later the same mistake was made by Wohler, who "knocked at the door of the Goddess Vanadis" so timidly.

It was nearly 30 years later that vanadium had its second birth and it was the young Swedish scientist Nils Sefstrom that stood at the cradle of the newborn infant. That was a time when metallurgy was making its first steps in Sweden and plants were going up in different parts of the country. At this point metallurgists noticed a curious phenomenon: the metal smelted from iron ores that had come from some deposits was brittle, while other ores yielded a metal of very high plasticity. How was that difference to be explained? Sefstrom was determined to find the answer. Studying the chemical composition of the ores from which the high-grade metal was smelted, he was able to prove by persistent experiments that they contained a new element, notably, the one del Rio had discovered and mistook for chromium. The new metal was named "vanadium".

Thus, neither Del Rio nor Wohler were destined to be the new element's "godfa-



ther", although both had been close to becoming one. After Sefstrom's success, Wohler wrote to a friend: "I was a real ass to have overlooked the new element in the brown lead ore, and Berzelius was quite right when he laughed at me and described, not without irony, how I knocked at the door of Vanadis, so feebly, bashfully and haplessly."

In Russia vanadium was found for the first time in 1834 in the lead ore of the Berezov mine in the Ural Mountains, and in 1839, in some sandstone occurring in Perm. Even at that early stage the Russian engineer Shubin observed the favourable effect of vanadium on iron and copper alloys. He wrote in one of his articles that "cuprous cast iron, black copper, refined copper and ingot copper are vanadium-base alloys, and it is probably the presence of this element that makes them very strong."

For many years no one was able to isolate pure vanadium. It was only in 1869 that the British chemist Henry Roscoe succeeded after an intense search in obtaining pure vanadium. But as a matter



of fact, it could be considered pure only by the standards of those times—it contained more than four per cent of impurities. And even small amounts of impurities change the properties of this element drastically. Pure vanadium is a silvery-grey metal possessing high plasticity which makes it forgeable.

But even the presence of minute amounts of such substances as nitrogen, oxygen and hydrogen renders the metal hard and brittle and not easily machined. For a long time it was considered extremely difficult to produce pure vanadium, because of its extraordinary activism at high temperatures. It was difficult to find a suitable metal for the crucible: vanadium dissolved them all during smelting and became impure. Scientists had to find another way. It was only recently that an electrolytic method of refining was designed, whereby vanadium pure up to 99.99 per cent was obtained. The significance of this development cannot be overestimated.

No industrial use could be found for vanadium for a long time. The 1907 world vanadium production was ... three tons,

and its price was fabulous—50000 gold roubles for one kilogram.

The miserly amounts of vanadium produced and the ridiculously high price had a simple reason: despite the fact that the earth's crust contains quite a quantity of vanadium—something like 0.2 per cent (which is 15 times more than lead and 2000 times more than silver), its accumulations hardly occur at all, which is why it is considered to be a rare metal. Ores containing one per cent of vanadium are regarded as exceptionally rich, and even ores containing a mere 0.1 per cent of this valuable metal are taken for industrial processing.

Curiously, the meteorites that hit the earth contain two to three times more vanadium than the earth's crust. Judging by the fact that the solar spectre shows a number of lines indicating atoms of vanadium, solar matter is also richer in this element than our planet is. It is probable that some time in the future the arrival of a consignment of vanadium-bearing ores, say, from Mars or Venus, will be regarded as no more than a regular transportation matter, but at this stage earthlings still have to rely on their own resources.

The difficulty of extracting vanadium from ores was the reason why this miraculous metal had had no use for several decades. But the rapid development of technology has now opened the door of industry wide for vanadium. The magnificent ability of this element to impart most valuable properties to steel has finally shaped its fate and role as a "vitamin" for steel.

A small addition (fractions of a per cent) of vanadium to steel makes it fine-grained, very resilient, very strong and better fit to resist impact and bending. It is not easily worn or ruptured, and it is exactly these qualities that motorcar components need so badly. This is why such important vehicle units and parts as the engine, valve

springs, suspension springs, axles, shafts and gears are manufactured from the inde-fatigable vanadium steel. This is why Henry Ford valued vanadium so highly. And it was for good reason that Academician Fersman said, "... fabulous are the powers that vanadium imparts to iron and steel, giving them hardness and strength, toughness and resilience, and indestructibility so essential for the automobile axle".

During the First World War a French plane equipped with a field-gun instead of the usual machine-gun caused a real sensation and scared the Germans to death. But how was it possible to mount a field-gun on board a plane? For the lifting power of the "flying bookcases" was very small. It appeared that it was vanadium steel from which the French field-guns were cast that had helped them up on board the planes. Of a comparatively light weight, they at the same time possessed remarkable strength characteristics, enabling airmen to shower German planes with devastating fire.

Subsequently vanadium steel began to be used for soldiers' helmets. They were light and thin and offered a reliable protection from bullets and splinters. Armour was needed also for the protection of gun crews at least from sharpshooters. For this purpose metallurgists in Sheffield manufactured armour steel that contained considerable amounts of silicon and nickel. But alas, during testing bullets easily went through the plates made from this metal. Then it was decided to use steel with an addition of only 0.2 per cent of vanadium. The result exceeded even the wildest expectations: the steel passed the most formidable strength tests in 99 cases out of 100!

Thus, vanadium began to serve not only offensive but also defensive purposes. American, French and British firms were willingly using vanadium in a variety of fields. But the German metallurgists, who



were believed to be great specialists in such questions, took what seemed a ridiculous stand: they were very sceptical about vanadium as an alloying element and all but refused to use vanadium steel. One of the German plants even declared that there was no sense in smelting it. That seemed paradoxical.

The mystery was cleared up soon: since the Germans had no vanadium ores of their own, they were not interested in letting the price of this metal on the world market soar along with the demand for it and tried their best to halt industrial application of vanadium steel. Meanwhile they themselves were busy looking for elements that could affect steel in the same way as vanadium. Alas, they soon realized that it would not be possible to do without the metal. That put an end to the attempts by metallurgical "diplomats" to defame vanadium steel, and its production continued to grow from year to year.

It is hard to even enumerate industries employing vanadium today, but the principal consumers include aviation, railway transport, electrical and radio engineering and defense industry.

The "services" of vanadium are enjoyed also by cast iron: from high-grade vanadium iron, piston rings, moulds, rolls and cold forging dies are manufactured.

But vanadium works not only as a vitamin-metal. Its salts, coloured green, yellow, red, black and golden (remember that del Rio called them panchromium—omnicoloured), are successfully used in the production of dyes and special ink, in glass making and in the ceramics industry. As a matter of fact, it was in ceramics that vanadium started out on its practical activity soon after it had been discovered by Sefstrom. By means of vanadium compounds porcelain and pottery pieces were coated in golden glaze and glass was tinted green or blue.



In 1842, the outstanding Russian chemist N. N. Zinin produced aniline, which had created a powerful impact on the development of the dye industry. Here too vanadium was welcome: it appeared that one gram of vanadium pentoxide was enough to transform 200 kilograms of colourless aniline salt into black aniline, a strong dye.

Modern chemistry cannot do without vanadium either: vanadium pentoxide is an excellent catalyst in the production of sulphuric acid which is called the "bread of chemistry". For many years platinum asbestos, i.e. asbestos coated with platinum powder, was used for this purpose. But that catalyst was both very expensive and unstable: it would often "refuse to work" because of gaseous contamination. This is why when the method of sulphuric acid production based on vanadium oxides as catalysts was worked out in the Odessa Chemical Institute, other sulphuric acid plants gave up the platinum asbestos catalyst. The valuable properties of vanadium are also used in the cracking of petroleum and in the production of many organic compounds.

Even ... pigs have given vanadium its due. Experiments carried out in Argentina have shown that the introduction of vanadium in the pigs' feed considerably increases their appetite and they gain weight fast.

Researchers at a Long Beach hospital (USA) studied the influence of vanadium on the growth of rats. One of the experimental groups whose ration was completely without vanadium grew at half the rate shown by their fellows in the control group which were given standard feed. But as soon as a little vanadium was added to their ration, normal growth was restored in just a few days.

Evidently vanadium is essential for the functioning of many living tissues: it has been discovered in eggs, fowl meat, cow

milk, animal liver and even the human brain.

It is a curious fact that certain sea plants and animals, including ascidians, holothurians, and sea urchins "collect" vanadium by first extracting it in some mysterious way from the environment. Some scientists believe that in this group of living organisms vanadium functions the same way as iron in the blood of the human organism and in higher mammals, that is, helps them to "breathe". Other scientists hold that marine life needs vanadium not for breathing but for eating. Further research will show which of these groups is right. So far it has been established that the blood of holothurians contains up to 10 per cent of vanadium, as for some ascidians, the concentration of vanadium in their blood is thousands of millions of times higher than in seawater. Really we can call them the vanadium banks of the sea! Scientists, naturally, have become interested in exploring the possibility of extracting vanadium by means of marine animals. In Japan, for one, plantations of ascidians stretch for kilometres on the sea coast. These animals are very fertile: one square metre of the plantation area yields up to 150 kilograms of ascidians. After the "reaping", the live vanadium "ore" is shipped to special laboratories where the much needed metal is extracted from it. Recently a press report said that the Japanese metallurgists have already produced steel in which the alloying element is vanadium extracted from ascidians.

A Soviet designing institute has been working on the project of a special seaweed picking vessel. It will be equipped with the latest navigation instruments, underwater TV cameras and various mechanical appliances. It is quite possible

that ships of this kind will soon be used as sea "ore-carriers".

Vanadium "collectors" are also to be found on the ground. One of them is the well-known death cup. Some species of mould are not indifferent to vanadium either: they simply cannot develop without it. In science plants that can accumulate some element are termed "bioconcentrators". They are often of great help to geologists, indicating as they do the presence of some valuable metal ores.

In 1971 Soviet palaeobotanists found in the spurs of the Tien Shan Mountains a plant unknown to science (they called it "menneria")—a unicellular alga that grew one and a half thousand million years ago. At this point our reader may begin wondering about what can vanadium have in common with an alga. But according to scientists, there is a direct link between the two: menneria, it seems, had played an important role in the formation of our planet's atmosphere and in the accumulation in the earth's crust of chemical elements, such as vanadium and uranium.

So much for the past and present of vanadium. And what about its future? What is the fate of this remarkable metal going to be?

It is hard to make forecasts now. But the wonderful properties of vanadium—considerable mechanical strength, great corrosion resistance, high melting point, and a specific weight smaller than that of iron—all enable us to suppose that in future vanadium will make an excellent structural material. But before that man must learn to take it from nature in much larger quantities than he does now, he must learn how to open nature's inexhaustible and jealously guarded "storehouses".

THE "RED LEAD" MYSTERY



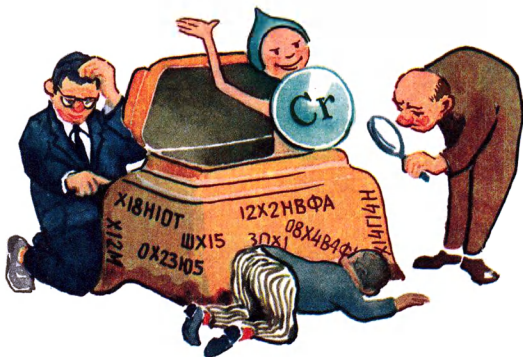
A lesson in hieroglyphics.—The Siberian red lead.
—Grey needles in the crucible. —Friends advise.
—Flares on the sun. —The French Academy registers
a discovery.—Fortune is well disposed.—Shocking
behaviour. —Carbon is contra-indicated. —Steel
becomes scaly. —Sensitive alloys. —The first patent.
—At a snail's pace. —Conversation with a German
metallurgist. —Not to be sold in bondage. —Ample
reserves. —Chrome-tanned leather boots. —Gods
shed their blood. —A way out. —A new speciality.
—Unrivalled.—Unexpected difficulties.—Drawing the
fire.—“Armour” for diamonds.—“The British know
what they are doing...”

Among the numerous designations of steels in any Soviet metallurgical handbook one is bound to come across many that include the symbol "X": X18H10T, X12M, 0X23H05, 11X15, 8X4B4Φ1, X14Г14H3T, 12X2HBΦA, 30XMIOA, etc. For the uninitiated this "cypher" is as mysterious as hieroglyphs. But a steelworker sees his way in these seemingly random combinations of letters and figures as easily as a musician reads his score. Even a cursory glance at these designations is enough to notice the common element in them: they all contain certain quantities of the element chromium (as indicated by the letter X—the Russian for Cr).

Along with its alloying "colleagues"—nickel, tungsten, molybdenum, vanadium, titanium, zirconium, niobium, etc.—chromium makes it possible to produce steels designed for a multitude of purposes. Steel used in modern technology must "know" many things: how to resist colossal pressures and chemical "aggressors", endure lasting overloads, yield to machining and resist heat and

cold. Chromium has its own part to play in "teaching" steel all these wonderful properties.

Back in 1766 I. G. Leman, a St. Petersburg professor of chemistry, described a mineral that had been found in the Berezov mine, 15 kilometres from Ekaterinburg (today Sverdlovsk) in the Urals. Treating the mineral with hydrochloric acid the chemist obtained an emerald-coloured solution with a white precipitate in which he discovered lead. A few years later (in 1770) Academician P. S. Pallas described the Berezov mines: "The Berezov mines consist of four pits that have been worked since 1752. Apart from gold, there is silver and lead ores mined there, and there also occurs a remarkable red lead mineral which has not been discovered in a single other mine in Russia. This ore comes in different colours (sometimes it looks like cinnabar), is heavy and semitransparent. Sometimes small, irregular pyramids of this mineral are imbedded in quartz like little rubies. When ground to powder, it makes a good yellow pigment ..." This mineral was given





the name "Siberian red lead". Subsequently it came to be called "crocoite".

At the end of the 18th century Pallas brought a specimen of crocoite to Paris. In 1796, the well-known French chemist Luis Nicolas Vauquelin, who had become interested in the mineral, made a chemical analysis of it. This is what he wrote about the results: "All specimens of this substance that are kept in several mineralogical rooms in Europe had been brought from this (Berezov—S.V.) gold mine. It used to be very rich in the mineral, but now they say that several years ago its reserves became exhausted and that today it is bought at the price of gold, particularly if it is yellow. Samples of this mineral that are of irregular shapes or broken into pieces can be used in painting where they are appreciated for their orange-yellow tint which does not change in the air ... The beautiful red colour, transparency and crystalline form of the Siberian red mineral are the properties that have aroused mineralogists' interest in its nature and the place where it comes from. Its substantial specific weight and the accompanying lead ore provide every

reason to suppose that the mineral contains lead ..."

In 1797 Vauquelin repeated his analysis. He boiled powdered crocoite in a potassium carbonate solution. The experiment yielded lead carbonate and a yellow solution which contained the potassium salt of a then unknown acid. When mercuric salt was added to the solution, a red sediment was formed and when it reacted with lead salt, it deposited a yellow sediment, and when stannous chloride was introduced, the solution turned green. After lead had been precipitated by means of hydrochloric acid, Vauquelin evaporated the filtrate and mixed the red crystals which had been formed (they were chromium anhydride) with carbon, placed it in a graphite crucible and heated to a high temperature. When the experiment was over he discovered in the crucible countless fused grey metal needles that weighed only a third of the weight of the starting material. Thus a new element was obtained. A friend of Vauquelin's advised him to give it the name "chromium" (from the Greek "chroma" meaning "colour") because of the bright and diverse colouring of its compounds. As a matter of fact, the component "chrom" is found in many words not associated with the element chromium. For example, the word "chromosome", translated from the Greek means "body which colours", an instrument called "chromoscope" is used to obtain a colour image; the popular photographic films bear the names "isopanchrom", "panchrom" and "orthochrom"; astrophysicists term some bright formations in the atmosphere of the sun "chromospheric flares", and so on.

At first Vauquelin did not like the idea of naming his metal "chromium" at all since it was of a modest grey colour which did not seem to fit that name. But still his friends persuaded him to accept it and after the discovery had been officially registered by the French Academy of

Sciences, chemists all over the world included "chromium" in the list of elements known to science.

Fortune appeared to be well disposed to the new metal. Its high melting point, extreme hardness and its ability readily to alloy with other metals, iron in particular, aroused the liveliest interest of metallurgists. This interest has not dampened over the years and today too metallurgy is the leading field in the consumption of chromium.

Chromium possesses all the properties typical of metals: it is a good heat conductor, an excellent electrical conductor, and, like most metals, has lustre. One curious fact sets it apart, though: heated to a temperature of about 37°C , it shows signs of "defiance". Many of its properties change drastically, by leaps and bounds. Its internal friction reaches its maximum, while its modulus of elasticity drops to its minimum. A sudden change also occurs in its electrical conductivity, the linear expansion coefficient and thermoelectromotive force. So far scientists have been unable to explain these anomalies.

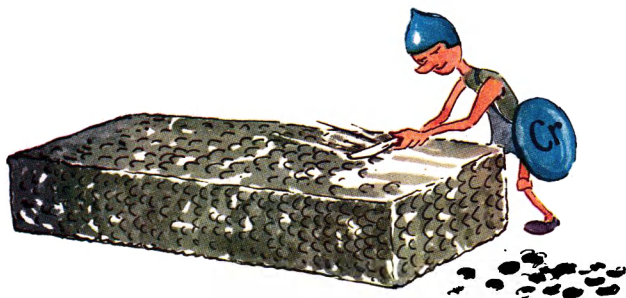
Even insignificant impurities render chromium very brittle which makes it practically impossible to be used as a stru-

ctural material, but as an alloy component, it has always been favoured by metallurgists. Even the addition of a small quantity of chromium makes steel hard and wear-resistant. These characteristics are indispensable in ball-bearing steel, which includes, along with chromium (1.5 per cent), also carbon (about one per cent). The chromium carbides precipitated in this steel are exceedingly strong, which is what enables it to resist wear, one of the worst enemies of metals.

Stainless steel which has good corrosion and oxidation resistance contains between 17 and 19 per. cent of chromium and between 8 and 13 per cent of nickel. But this steel is averse to carbon since excessive quantities of it are bonded into carbides precipitated on the boundaries of the steel grains, reducing the chromium content in the grains themselves and making it hard for them to resist the action of acids and oxygen. Therefore, stainless steel must not contain more than a minimum (0.1 per cent) of carbon.

At high temperatures steel may become scaly. Some machine parts heat up to hundreds of degrees. To ensure that the steel from which the parts are made does not "suffer" from this malady an addition of 25 to 30 per cent of chromium is





sufficient. Such steel will withstand temperatures of up to 1000°C .

Nichromes—alloys of nickel, chromium and iron—make good heating elements. The introduction of cobalt and molybdenum to these alloys enables the metal to withstand great loads in the $650\text{--}900^{\circ}\text{C}$ temperature range. From them the blades of gas turbines are manufactured. An alloy of cobalt, molybdenum and chromium (comochromium) is harmless for the human organism, hence its application in reparative surgery.

An American firm has recently developed some new materials in which magnetic properties change under the effect of temperature. According to scientists, these materials which are based on compounds of manganese, chromium and antimony will find application in many automatic devices sensitive to temperature changes. They will successfully replace more expensive thermalloys.

Today the bulk of the world chromium ore output is turned over to ferroalloy plants producing a variety of ferrochromium alloys and metallic chromium.

Ferrochromium was produced for the first time in 1820 by reduction of ferric and chromic oxides by charcoal in a crucible. Pure metallic chromium was obtained in

1854 by electrolysis of water solutions of chromic chloride. The first attempts to smelt carbonic ferrochromium in a blast furnace were made at about the same time. The first patent for chromium steel was issued in 1865. The demand for ferrochromium began to grow rapidly.

Electricity, or more exactly, the electrothermal method played a crucial role in the production of metals and alloys. In 1893 the French scientist Moissan smelted carbonic ferrochromium in an electric furnace which contained 60 per cent of chromium and 6 per cent of carbon.

In prerevolutionary Russia ferroalloy production developed at a snail's pace. The plants in the south smelted miserly amounts of ferrosilicon and ferromanganese. In 1910 the Poroghi, a small electrometallurgical plant, was built on the river Satka (Southern Urals). It started the production of ferrochromium and later, ferrosilicon, but still it was too small to meet the national demand for these alloys and Russia had to import them almost wholly from other countries.

After 1917, the young Soviet state could not let itself be dependent on the capitalist countries in a field of such vital importance as the manufacture of high-

grade steels which was the main consumer of ferroalloys.

Implementation of the great industrialization plans largely depended on the availability of steels—structural, tool, stainless, ball-bearing, motor and tractor. And these steels had chromium as one of their principal components.

Between 1927 and 1928 the planning and building of ferroalloy plants began. The Chelyabinsk ferroalloy plant, the first of its kind in the Soviet Union, was commissioned in 1931.

V. S. Yemelyanov, Corresponding Member of the USSR Academy of Sciences, one of the founders of the Soviet quality metals making industry, who during that period was in Germany studying the experience of metallurgical plants there, recalls this curious conversation in his memoirs:

"In 1933 I asked the chief engineer at a small German plant, 'To whom do you sell ferrochromium made by this plant?'"

"He began to enumerate: 'Something like five per cent of the output we sell to nearby chemical plants, the Becker plant buys two per cent, some three per cent ...'"

"Does the Soviet Union buy much from you?" I interrupted him.

"Well, it depends. But usually we send 75 to 80 per cent of our output to your plants. And, as a matter of fact, we work on the chromium ore from the Urals."

Indeed in those days Soviet chromium ore was exported not only to Germany, but also to Sweden, Italy and the United States. And that's where we bought our ferrochromium.

That state of affairs came to an end when two ferroalloy plants were built in Zaporozhe and Zestafoni in 1933. Since then the Soviet Union stopped importing major ferroalloys and was soon even able to export them. The national industry had practically fully been supplied with the ferroalloys it needed.

Addressing the 17th Congress of the Communist Party of the Soviet Union,

Sergo Ordzhonikidze, People's Commissar for Heavy Industry, said: "... if we did not have high-grade steels, we would not have had the motor and tractor industries. The price of the high-grade steels we are now using is more than 400 million roubles. If we had to import them, we would have to pay 400 million roubles annually. That would, sure as hell, have pushed us right back into the clutches of capitalism."

In 1936 immense deposits of chromite, the main raw material for the production of ferrochromium were discovered near Aktyubinsk in Kazakhstan. The Aktyubinsk ferroalloy plant which was built on the basis of this deposit during the war subsequently became a major enterprise putting out ferrochromium and chromium of all grades.

Abundant reserves of chromite are also found in the Urals. Among the most industrially important deposits are the Saranovsk, Verbyuzhyegorsk, Alapayevsk, Monetnaya Dacha and Khalilovsk. The Soviet Union holds a leading place in the world in the explored reserves of chromium ores.

Outside the Soviet Union chromium ore deposits are situated in Turkey, India, New Caledonia, Cuba, Greece, Yugoslavia and in some African countries. Meanwhile there is absolutely no chromium in some advanced industrial countries, including Britain, France, Federal Republic of Germany, Italy, Sweden and Norway. The ores the United States and Canada have are so poor that they are practically useless as a ferrochromium raw material. Incidentally, the chromium content in the earth crust comes to 0.02 per cent.

Chromites have a vast use in the refractory materials industry. A combination of magnesite and chromium is excellent for the manufacture of firebricks used to line open-hearth furnaces and other metallurgical equipment. Such bricks not only resist heat, but are also indifferent to repeated and drastic temperature changes.

In chemistry chromites are used for the production of the biochromates of potassium and sodium and of chrome alum used in tanning to make leather shiny and durable. Such leather is called "chrome leather", hence, "chrome boots", that used to be so highly regarded in Russia.

Justifying its name as it were, chromium is indispensable in the production of dyes for the glass and ceramics industry and for the textile industry.

Every evening the ruby stars of the Kremlin light up the Moscow sky. Among the precious stones ruby is second only to diamond. According to an old Indian legend, rubies are drops of blood shed by gods. This is how it tells about their origin: "Heavy drops of blood fell onto the bosom of the river, into the deep waters and the reflection of beautiful palm trees. And then the river began to be called Rawanaganga, and the drops of blood that had turned into ruby gems began to glow, and as darkness descended, they glowed with a magic fire which burned inside the gems and pierced the waters with its hot rays ..."

Today the technique of making the beautiful red gem has become much simpler and gods do not have to shed their holy blood; it is replaced by aluminium oxide with an addition of chromium oxide (to this substance ruby crystals owe their beautiful colour). But it is not merely their appearance that explains the value of artificial rubies: born with their help, the laser works miracles like that magic ray created by engineer Garin's "hyperboloid" and Alexey Tolstoy's rich imagination. The laser is capable of cutting any metal as easily as scissors cut paper, or making the finest perforations in diamonds, corunda and other such "hard nuts", completely ignoring their universal reputation for toughness.

Chromic oxide enables tractor manufacturers to reduce considerably the engine

running-in time, an operation required in order to let the rubbing parts of the engine "get accustomed to each other". It used to be a lengthy process to which tractor builders could not be reconciled. The way out was found when a new fuel additive containing chromic oxide was developed. The secret of its effect is simple: when chromic oxide burns it forms tiny abrasive particles, which, after settling on the inside walls of the cylinders and other surfaces subjected to friction, smooth out all rough spots, polish the components, and firmly adjust them to each other. Combined with the use of a new lubricant, this additive has made it possible to reduce running-in time to a thirtieth of what it was, before.

Not long ago chromium was given yet another "job": American engineers manufactured an experimental magnetic tape, the working layer of which contained, instead of particles of ferric oxide, particles of chromic oxide, which dramatically improved the quality of recording and made the tape more reliable in operation.

Chromium "finds" itself a lot to do in many fields, including the manufacture of photographic materials, drugs and chemical catalysts and also in metal coatings. Chrome coatings deserve, we believe, a more detailed description.

It was noticed a long time ago that chromium was not only extremely hard (as far as this property is concerned, it has no rivals among metals), but also effectively resisted corrosion in the open air and did not react with acids. Attempts were made to coat articles from other metals with chrome electrolytically to protect them from corrosion, scratches and other "traumas". It was found, however, that chrome coating was porous, easily peeled off and did not justify the hopes that had been pinned on it.

For nearly 75 years had scientists grappled with the problem of chrome plating and it was only in the 1920s that



solution was found. The failure was explained by the fact that the chromium used in the electrolyte of the chrome bath was trivalent which could not make the required coating. It was found that it was six-valent chromium that was needed. Since then chromic acid, whose chromium valence was six, began to be used as the electrolyte. The protective coatings (on some external parts of automobiles, motorcycles and bicycles) are up to 0.1 millimetre thick, but when used for decorative purposes (in the finish of clocks and watches, door knobs and other objects not seriously endangered by corrosion) they may be exceedingly thin—0.0002 to 0.0005 millimetre.

Another method of chrome plating is the diffusion process, whereby the plating takes place in a furnace and not in the chrome bath. In the early stages of development of this process the steel part being coated was placed in chromium powder and then heated in a reducing atmosphere to a high temperature. A chromium-enriched layer was thus form-

ed on the surface of the steel part. In hardness and corrosion resistance that coating was vastly superior to the steel from which the part was made. But in that process too some "buts" were discovered: at a temperature of about 1000°C chromium powder began to sinter, and besides, carbides preventing diffusion of chromium into steel precipitated on the surface of the metal which was being plated. Another chromium-carrier had to be found. The introduction of chloride or iodide, the volatile chromium haloids, made it possible to lower the temperature of the process.

Chromic chloride (iodide) is produced directly in the chrome-plating furnace by passing the vapours of a corresponding halogen acid through chromium or ferrochromium powder. The resultant gaseous chloride (iodide) envelopes the object being plated, saturating the external layer with chromium. It becomes bonded with the basic material much more firmly than when the chrome plating is done galvanically.

Chemists in Lithuania have developed a process of creating a multi-layer "coat of mail" for especially vital components. The extremely thin outward layer of this covering (and it does look like mail under the microscope) is chromium. During service it is the first to be attacked by oxygen but years will pass before it will become oxidized and all this time the component it covers will be doing its important duty.

Until recently only metal parts were chrome-plated. But now Soviet scientists have developed a process of chrome-plating plastics. When tested, chrome-plated polystyrene, the well-known polymer, proved to be much stronger and was not affected by some of the worst of the known "enemies" of structural materials—wear, bending fatigue, and impact. And the service life of the parts made from this material has naturally become longer.

The chrome "armour" has been proved useful even for diamonds that are themselves rightly considered the standard of hardness. It appears that not all the diamonds mined can be used in tools. As a rule, natural diamonds have a patina of tiny cracks, making it impossible to use them in cutters or bits: as soon as such diamonds come into contact with hard rock they break into small splinters or crumble out of their holders. Scientists have suggested that the diamonds should

be protected by a thin coating of chromium which bonds well both with the diamonds and the copper holders.

The metal-coated diamond was tested and it was proved that it was not only secure in the holder, but the service life of the crystal itself became several times longer. A microscopic examination of the crystal revealed that one of the facets had quite a deep crack "cemented" by the film covering the diamond. It became clear that the atoms of chromium combining with the diamond's carbon had formed hard carbides on its surface and that chromium had penetrated into the crack whose walls became covered with carbide "armour". Meanwhile the layer of pure chromium that was in contact with the holder had fused with copper, owing to which the diamond became firmly fixed in the tool. Thus, chromium made it possible to "kill two birds with one stone": the tool became more durable and the diamond became harder than ... diamond.

... Before winding up our story about chromium, we would like to quote V.S. Yemelyanov once more. In 1967 he wrote: "Two years or so ago I heard a news which, alas, passed unnoticed in our country. We had sold a consignment of ferrochromium to Britain, a country which we had always taken for a symbol of technological progress. And now Britain buys our ferrochromium! And the British know what they are doing."

IRON'S OLD COMPANION



Columns of an underground palace. — Magic black powder. — “Glass soap”. — Gahn or Kaim? — The search is continued by Scheele. — The “infernal fire” does its job. — Hadfield obtains a patent. — Try breaking a safe. — The bell will not sound. — Replacing platinum and palladium. — Known since childhood. — According to modest estimates. — The Vityaz is plying the oceans. — Bacteria played their part. — Trapped by an underwater cable. — Thrown overboard. — For work in abyssal depths. — “Parcel” from space. — Did Russia need it? — The road leads to the open-hearth furnace.

Those who have been to the Moscow Underground could not have missed the Mayakovskaya Station, one of the most magnificent subway palaces supported by columns finished with a beautiful pink stone along their edges. The stone is rhodonite, a mineral containing manganese. The delicate pink colour ("rhodon" in Greek means "pink") and good workability make it an excellent finishing material which is also good to carve various articles from. Articles made from rhodonite are kept in the Hermitage and the Peter and Paul Cathedral in Leningrad and in many other museums. Large rhodonite deposits occur in the Urals (once a lump weighing 47 tons was discovered). Nowhere else in the world do such impressive accumulations of this mineral occur, neither is the Urals rhodonite surpassed in its beauty.

But the main manganese-containing mineral of industrial importance is pyrolusite or manganese dioxide, a black mineral with which man has been familiar since old times. Even Pliny the Elder, the outstanding naturalist of ancient Rome who died in the eruption of Vesuvius in the 1st century AD, mentioned the wonder-

ful ability of the black powder (young pyrolusite) to brighten glass.

Then, in 1540, Vanoccio Biringuccio, the Italian scientist and engineer, wrote in his encyclopedic work on mining and metallurgy entitled *Pyrotechnia*: "... pyrolusite may be coloured dark brown; ... if vitreous substances are added to it, it gives them a beautiful violet colour. The master glass-makers use it to colour glass; the master potters make violet designs on their wares with it. Furthermore, pyrolusite has one special characteristic: when alloyed with molten glass it purifies it and makes it white instead of green or yellow."

The name "pyrolusite" was given to the mineral much later and in the Middle Ages it was called "glass soap" for its ability to decolourize glass, or "manganese" (in Greek "manganese" means "purify"). It had still other name too—"black magnesium" since pyrolusite had been mined from ancient times near the town of Magnesia in Asia Minor. It was also there that "white magnesium" ("magnesia alba" or magnesium oxide) was extracted.

The history of chemistry ascribes the discovery of manganese as a metal to the Swedish chemist, J. Gahn (1774). But there is reason to suppose that the first grains of metallic manganese were obtained by Ignatius Gottfried Kaim, who had described it in his thesis which was published in Vienna in 1770. Kaim had not completed his research and it remained unknown to most chemists of the time. But one chemical handbook does mention Kaim's discovery: "By heating a mixture of one part of pyrolusite powder with two parts of black flux Kaim produced a bluish-white brittle metal in the form of a crystal with numerous differently-outlined lustrous facets, in which a fracture is iridescent with every tinge, from blue to yellow."

The next attempt to find out more about manganese was made by the Swedish chemist Tornberg Bergman. "The mineral



that they call 'black magnesium' is a new earth that should not be confused either with roasted lime nor with 'magnesium alba'." But still Bergman was unable to extract manganese from pyrolusite.

Bergman's study was continued by his friend, the well-known chemist Carl Scheele. In 1774, he submitted his paper "On Manganese (i.e. pyrolusite—S.V.) and its Properties" to the Stockholm Academy of Sciences in which he reported on the discovery of a new element—gaseous chlorine, and asserted that pyrolusite contained a new metal which was different from all known at that time. But he too failed to obtain it.

Gahn succeeded in what both Bergman and Scheele had failed in the same year—1774. He placed a mixture of ground pyrolusite and oil in a crucible the inside walls of which were covered with wet charcoal dust and put some of the dust on top. After an hour of intense heating a grain of metallic manganese was discovered in the crucible. That discovery brought Gahn world fame and the family of metals a new, fifteenth, member.

On May 16, 1774, Scheele sent Gahn purified pyrolusite with a note saying: "I'm anxiously waiting for your report on the results you will get when you apply your 'infernal fire' to this pure pyrolusite and I hope you will send me a small regulus of the metal as soon as possible."

The "infernal fire" did its job and on June 27, only a month later, Scheele wrote Gahn in gratitude for the regulus of manganese: "... I think that the regulus obtained from pyrolusite is a semimetal different from all the semimetals and having a close relation to iron."

Manganese began to be produced in Russia in the first quarter of the 19th century as an alloy with iron—ferromanganese. *The Mining Journal* mentioned steel smelting with the introduction of manganese in 1825. Since then the fate of this element has been

inseparably linked with metallurgy. Today too it remains the main consumer (95 per cent) of manganese ore.

In the now classical work *On Damask Steels* published in 1841, the outstanding Russian metallurgist P. P. Anosov described the results of his study of steels with different manganese content. For introduction into steel Anosov used the ferromanganese obtained in crucibles. From 1876 industrial smelting of ferromanganese began at the Nizhni-Tagil plant.

The year 1882 became a landmark in the history of manganese—the British metallurgist Robert Hadfield produced steel with a 13-per-cent manganese content. It was in 1878 that the 19-year-old metallurgist of Sheffield began studying alloys of iron with other elements, and particularly, with manganese. Four years later Hadfield made the following entry in his log-book: "I started these experiments intending to make steel that would be hard and at the same time malleable. The experiments have yielded some curious results, quite important and capable of changing metallurgists' current views on the alloys of iron."

In 1883 Hadfield was issued the first British patent for manganese steel prepared on the basis of a rich ferromanganese addition to iron. He continued studying problems of manganese steel and published his findings in several books dealing with the application of manganese in metallurgy, with some newly-discovered properties of iron and manganese and with manganous steel. He established that water quenching gave steel new wonderful properties. He obtained several more patents concerned with the thermal treatment of manganous steel and in 1901 patented his design of a furnace intended for heating this steel before hardening.

Hadfield's steel soon won the recognition of metallurgists and engineers.

Owing to its high wear-resistance, it began to be used for parts subject to excessive wear under high pressure — rail frogs, crusher jaws, tumbling balls, caterpillar tracks, etc. But the most amazing fact was that under the effect of load the steel from which those components were made became increasingly harder. The following explanation was found. After casting, extra carbides settle on the grain boundaries of steel reducing its strength. These carbides are dissolved in the metal by means of hardening. During service carbon is released in the surface layer as a result of work hardening (under the effect of load) and steel becomes stronger.

Small wonder, therefore, that Hadfield's steel aroused the liveliest interest of firms manufacturing safes and locks.

Manganese iron is also characterized by the self-hardening property. Excavators with bearings made from this iron were in service without repairs twice as long as their "fellows" with bronze bearings.

Manganese is extensively used in metallurgy for deoxidation and desulphurization of steel. It is used as an alloy element in spring steels, steels for oil and gas pipelines and in non-magnetic steels.

As a matter of fact, there is hardly any need to enumerate the manganese-containing steels: the element discovered by Gahn is present in a certain quantity in literally all the steels and irons. It is for good reason that it is called iron's eternal companion. In the Periodic Table manganese and iron occupy neighbouring "cells" (Nos. 25 and 26). (Together with iron, manganese even finds its way into sharks' teeth, but more about it later.)

After the Russian scientists S. F. Zhemchuzhny and V. K. Petrashevich discovered in 1917 that even small additions of copper (about 3.5 per cent) make manganese more ductile, metallurgists became interested in manganese alloys as well.

Modern technology applies a large number of manganins, that is, alloys of manganese, copper and nickel, characterized by high electrical resistivity which is practically independent of temperature. The work of electric manometers is based on the ability of manganin to change resistance under pressure. A common manometer cannot be used when it is necessary to measure a pressure of several scores of thousands of



atmospheres: the liquid or gas inside the manometer tube breaks through its walls, no matter how strong the material from which it is made. This task is successfully coped with by the electric manometer: measuring the electrical resistivity of manganin under definite pressure it is possible to calculate pressure to any degree of accuracy on the basis of a definite formula.

Manganins are characterized by another valuable property: damping, that is, the ability to absorb the energy of oscillations. Had it occurred to anyone to cast a bell from manganin, it would hardly be possible to use it at all: instead of the resounding boom the manganin bell would produce short thumps.

But it must be said that while "dumbness" is clearly a shortcoming in a bell, it is fine in such "sonorous" parts as tram wheels, rail joints and many other things that can produce unnecessary rumbling. "Mute" alloys can considerably lower the harmful noise level in forging and stamping shops. The greatest ability to "keep quiet" is displayed by alloys consisting of 70 per cent of manganese and 30 per cent of copper. Some of them are not inferior to steel in strength.

Interestingly enough, manganese bronze—an alloy of manganese with copper—can be magnetized even though neither of the components have magnetic properties.

Alloys possessing "memory" have become rather well-known during the last few years (you will read about the best-known of them, nitinol, in the chapter entitled "The Copper Devil"). The number of such alloys has been growing steadily. Recently a group of researchers under Ye. M. Savitsky, Corresponding Member of the USSR Academy of Sciences at the A. A. Baikov Institute of Metallurgy, developed an alloy on the basis of manganese (with an addition of copper) which even exceeds the famous nitinol in



its ability "to remember" its former shape. It is easily manufactured and machined and will doubtlessly find quite a number of fascinating spheres of application.

For a long time expensive metals, such as palladium and platinum, had been used as catalysts in the production of superpure nitrogen. The Inorganic Chemistry and Electrochemistry Institute of the Georgian Academy of Sciences has developed a process in which manganese acts as the catalyst. The first industrial facility for the production of ideal nitrogen from the air, essential for the manufacture of kapron, has been built at the Rustavi Synthetic Fibre Plant.

We are all familiar with one manganese compound—potassium permanganate. It is the solution used as a disinfectant to bathe a wound, rinse a sore throat or treat a burn. It is also widely applied in chemical laboratories for manganometry, i.e. quantitative analysis.

Just as many other elements, manganese is absolutely essential for the normal development of animals and plants.

Generally, the content of this element in the living organism is not more than several thousandths of one per cent, but some flora and fauna species show

a special interest in it. For example, red ants contain 0.05 per cent of manganese; up to one per cent of manganese is contained in rust fungi, sea weed and water nut. In certain bacteria the manganese content may be as high as several per cent. The human organism needs daily from 3 to 5 milligrams of manganese, the blood containing 0.002-0.003 per cent of it.

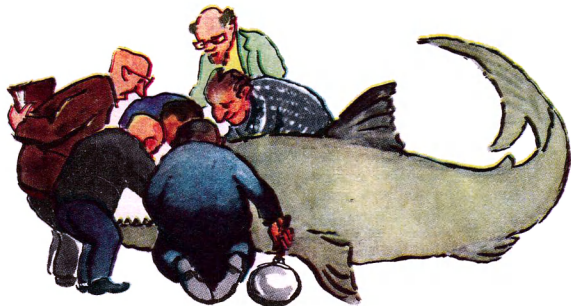
A few words about the shark we have mentioned, while we are on the subject of plants and animals. Scientists who studied the tooth of this marine carnivore which had lain on the ocean floor for several thousand years found that the tooth was still in a good state except that it had become covered with iron and manganese compounds. How had these elements managed to end up there?

Some hundred years ago, in 1876 to be more exact, the *Challenger*, a British three-mast sailer which had been on a scientific expedition, plying the seas and oceans for more than three years, brought to Britain, together with her other "spoils", some mysterious dark cone-shaped lumps which had been lifted from different regions of the ocean floor. Since manganese was the principal component of the "cones" they

came to be known as "manganese nodules", or iron-manganese concretions in more scientific terms. Later expeditions revealed that there are tremendous accumulations of "manganese nodules" in many parts of the ocean floor. But no particular interest was shown in them up to the middle of this century. And it is only in recent years and owing to the comparatively insufficient reserves of manganese ore in the world, that the underwater treasure has aroused scientific interest.

The regions of accumulations have been carefully studied, revealing startling results. According to preliminary (and it can definitely be said, modest) calculations, nearly 100 thousand million (!) tons of excellent iron-manganese ore has accumulated in the Pacific alone. And the word "ore" is no slip of the tongue: the concentration of manganese in it comes to 50 per cent and of iron, to 27 per cent. (In some concretions the content of manganese dioxide is 98 per cent and it can be used without preliminary processing in the manufacture of electric batteries, for instance.)

As wealthy is the Atlantic, and as far as the Indian Ocean is concerned, the Soviet



expedition on the *Vityaz* has discovered iron-manganese concretions on the bottom of this ocean too. Calculations show that the reserves in the Indian Ocean are at least as big as in the other oceans.

Oceanographers believe that the concretions are a result of concentration around a body of minerals dissolved in water solutions. Some scientists maintain that a certain part in this process is played by marine bacteria, those microscopic "ore-dressers" of the sea. Biologists in Leningrad have discovered hitherto unknown species of so-called "metallo-genic" bacteria capable of extracting manganese from water and concentrating it. In a laboratory experiment the "underwater metallurgists" demonstrated enviable efficiency: they created manganese concretions the size of a match-head within two or three weeks. Amazing productivity, considering that the "toilers" themselves are hardly discernible under the microscope.

The oceanic concretions are not unlike potato tubers and their colouring ranges between brown and black, depending on whether it is iron or manganese that predominates in the composition. If the content of manganese is high, the colour is absolutely black.

The size of the concretions varies from fractions of a millimetre to 15 centimetres. But considerably larger accumulations are also found. The collection of the Scripps Oceanographic Society has a 57-kg concretion which was found in the vicinity of the Hawaii. A still larger concretion, one weighing 136 kilograms, was discovered stranded in the loops of the underwater telegraph cable when it was being hoisted for repairs. But that unique specimen was not destined to become a museum exhibit; after it had been studied and a drawing of it made, it was thrown overboard because of a misunderstanding. But even that record was broken when the *Vityaz* expedition in the

Pacific fished out a lump one and a half metres long: it weighed almost a ton.

Many countries have now really become interested in the development of underwater resources. Scientists and engineers, naturally, will yet have to find answers to the most complex technological problems involved in underwater mining. Under construction today are special submarines, amphibious tractors, excavators on pontoons and other such facilities intended for the extraction of the treasure stored in the underwater abyss. "Ocean mining" will have an indisputable advantage over the mining industry as we know it today: it will not need the laying of roads and other communications which would be indispensable on the surface. Boats will take people and equipment to any part of the ocean and will ship the minerals extracted to any destination. Dutch engineers have designed an underwater caterpillar automatic excavator intended to collect manganese and other ores on the seabed. This automatic "miner" will be able to work at a depth of up to five kilometers. It will be electrically-driven and remote-controlled by a TV camera operator on board the ocean ore carrier. The spiral rotor of the excavator will pick up a certain amount of ore and empty it into its hull. Scientists and engineers in Japan are now developing a bathyscaphe to carry out underwater prospecting for oil and manganese and do other survey work. A 30-ton displacement bathyscaphe intended for three people will be able to submerge to a depth of up to two kilometres, move at considerable speed, have good manoeuvrability, and stay underwater for more than three days and nights without surfacing. Their next project which will be launched at the beginning of the 1980s is an oceanographic submarine to carry out geological survey and study fish reserves of the ocean at a depth of up to 6 kilometres.

Important work designed to put the wealth of the oceans to use is under way in the Soviet Union as well. Hundreds of expeditions every year go out to the seas and oceans that cover more than 70 per cent of the earth's surface. The time is not far off when industrial exploitation of the world ocean resources will begin but right now geologists and miners have enough to do exploring the earth's depths.

In content in the earth's crust manganese is in 15th place (0.09 per cent). According to geologists, almost all manganese deposits are more or less "coevals". This has given scientists reason to hypothesize a cosmic origin of the manganese accumulations. Their theory is that some two thousand million years ago meteoritic dust rich in manganese had precipitated on the earth surface, forming the manganese deposits found today in the ground and on the sea and ocean floor.

Manganese ores occur in India, Ghana, the South African Republic, Morocco and Brazil. But not one of these countries can

compete with the Soviet Union in this respect. The Chiatura manganese deposit situated in Soviet Georgia is the world's biggest. It is a curious fact that the small river Rioni flowing in these parts dumps more than 100 000 tons of manganese into the Black Sea every year.

The production of manganese at Chiatura was started as early as 1879, and in 1886 another big deposit began to be developed near Nikopol. Tsarist Russia, however, "had no need" for manganese: 1 195 thousand tons of the 1 245 thousand it had produced in 1913 was exported to other countries. During the Great Patriotic War intensive development of manganese deposits began in the Urals, Kazakhstan and Siberia. Today the Soviet Union leads the world in the production of this valuable mineral.

Ferroalloy plants are the main consumers of manganese ores. The processes introduced there yield alloys of manganese with iron or silicon, or the pure metal. From there manganese is shipped to steel-making shops.

A GREAT TOILER



Is iron hunger imminent?—Love calls for sacrifice.—Have some iron filings to eat.—In a gold setting.—The natives' "iron" thirst.—King Solomon's feast.—A "celestial stone".—Facts are stubborn things.—A crater in Arizona.—The Bronze Age retires.—A magic wand.—Peter I's fury and grace.—Test the strength of your mail.—"Frol Fooks shall be whipped".—Demidov sends a pursuit party.—A wonder ship.—Eiffel and sceptics.—Sun palaces.—Make your wish.—"Wooden" steel.—Do not blame iron.—Is it time to retire?—The Atomium in Brussels.

The "iron hunger" was among the major problems on the agenda of the 1910 International Geological Congress in Stockholm. A special commission which had been entrusted to make an estimate of the world iron reserves submitted its report to the Congress. According to it, sixty years from then, that is, by the year 1970 the world iron resources would be completely exhausted. Fortunately the learned men on the commission proved to be poor oracles: even today humanity is in no need of restricting its use of iron. But what if their prediction would have come true and there would have remained not a gram of this element in the world? Here is what the outstanding Soviet mineralogist Academician Fersman thought about it:

"... In the streets havoc would reign supreme: there would be no rails, no railway cars, no locomotives, no automobiles, not even cobblestones, for they would have turned into a clayey pulp, while the plants would have faded and died without the vital metal.

"Destruction would have swept the Earth like a hurricane and the death of humanity would have become imminent.



"But as a matter of fact, humans would not have even lasted till then: having been deprived of the three grams of iron in their organisms, they would have died out before the events just described would have unfolded. To lose all iron—five-thousandths of one per cent of body weight—would have spelled death for them!"

Quite a future, one must admit! Indeed, iron is vital to our existence. No animal life would have been possible without it: iron is in the blood composition of all the representatives of the animal kingdom of our planet. Bivalent iron—the substance carrying oxygen throughout the tissues of any living organism—is a vital component of hemoglobin. It is iron that gives blood its red colour. Although it is true that the blood of some worms, which also contains iron, is green. Not long ago a Soviet Antarctic expedition discovered an unusual pike in the Indian Ocean: its blood was colourless and transparent like water. It was established that the content of iron in its blood was only a tenth of that in fishes with red blood. Iron was first discovered in the human blood by the French scientist Mery in the past century. One story associated with this discovery is that on learning about iron in the blood, a student of chemistry who was in love at the time decided to make his sweetheart a ring from the iron of his blood. He let his blood regularly, then treated it chemically and produced iron. But it is said that he died of anaemia still without having collected the necessary amount of iron: it is only three grams of it that the human body contains.

A person with a low iron content in his blood easily becomes tired, suffers from headaches and is generally in low spirits. Even in old times people knew prescriptions of various "iron" drugs. In 1783 the *Economic Journal* wrote: "In some cases iron proper makes a very good drug, and the finest iron filings can be taken

with benefit either as they are or sugar-coated." The same article also recommended other preparations: "iron snow", "iron water" and "steel wine" ("a sour grape wine, such as Rhine wine, infused with iron filings, will become iron or steel wine which is an excellent drug").

It goes without saying that in the second half of the 20th century patients do not have to swallow filings, but numerous iron compounds are indeed widely applied in modern medicine.

Iron is also found in some mineral springs. Here is a story about how the first iron mineral spring was discovered in Russia. In 1714 Ivan Rebovey, a worker at the Konchezersk copper smelting plant in Karelia who "suffered from a pain in the heart and could hardly drag his feet", one day saw a spring on a ferrous bog not far from Lake Ladozhskoye and began to drink from it. "He drank for three days in a row and was cured." The story was related to Peter I and soon his "Decrees Concerning the Martian Waters at Olonets" were published. The name "Martian" was derived from Mars, the god of war and iron. The tsar himself came there with his family and drank the curative water. But when he died, the spring was forgotten for a long time to come.

Medicinal properties had been ascribed to iron from time immemorial also owing to its remarkable magnetism. Ancient Egyptians, for example, were convinced that immortality could be attained by means of a magnet and recommended sick people to take iron filings. The ancient Greek physician and researcher Galen asserted that the magnet had a laxative effect, while Avicenna treated hypochondriacs with it.

It is not only animals but also plants that need iron. Far back at the very beginning of the 18th century the French chemist and physician Nicolas Lemery discovered iron in the ashes of burnt grass

blades. Later it was found that this element was in the composition of all the plants since it was absolutely essential for the formation of chlorophyll. There is iron in the respiratory enzymes and it exerts a considerable influence on the respiration rate of plants. It is an interesting fact that the plankton consumes as much as 500 000 tons of iron a year, that is, something like the amount annually produced by all the world's steel works.

Hardly any other element in the Mendeleyev Table has been associated as intimately with the history of civilization as iron. Over the ages and millennia has man preserved his respect for iron and for people who work it. Some ancient peoples treasured iron more than gold. Only the wealthiest nobility could afford wearing iron decorations which were often set in gold. In ancient Rome even wedding rings were made of iron. Gradually, as metallur-





gy developed, iron became cheaper and more available. But still it is known that even in recent times some backward tribes were ready to pay fabulous prices for it. The famous British explorer of the 18th century James Cook described the attitude to iron shown by Polynesian natives: "... Nothing attracted the visitors on our ships as much as this metal; iron had always been for them the most coveted, most precious commodity." One day Cook's men managed to get a whole pig for a rusty nail. On another occasion the islanders gave so much fish to the sailors for a few old knives that it lasted the crew for many days.

The trade of blacksmith had been considered one of the most honourable in all times. This is what one legend dating from three millennia back relates.

When the construction of King Solomon's Temple ended in Jerusalem, the King gave a feast to which he invited all the workmen who had been engaged on the tremendous construction site. When the guests were seated and ready to try the viands King Solomon suddenly said:

"And who is the main builder here?

Whose was the greatest contribution to the creation of this magnificent temple?"

A mason got up and answered:

"The temple is the work of our hands, no doubt about it. We masons built it stone by stone. Take a look and see how strong the walls, the arches and the vaults are. It will stand for ages to the glory of King Solomon."

"The foundation of the temple is indeed made of stone, I'll admit," a carpenter intervened. "But think, dear guests, what would this temple look like if my comrades and I had not worked by the sweat of our brow on it. Would you like the sight of its bare walls had we not finished them with mahogany and Lebanese cedar? And our parqueting of the best species of box tree—you can feast your eyes on it! We carpenters can rightly consider ourselves to be the genuine creators of this beautiful palace."

"No, you must get at the root of the matter," a digger cut in. "I'd like to know how these boasters," he nodded in the direction of the mason and the carpenter, "would've put up the edifice if we had not dug the foundation ditch. Your beautiful

walls would have crumpled together with their finishings like a house of cards at the first blow of wind!"

But it was not for nothing that King Solomon was considered wise. He beckoned to the mason and asked him:

"And who made your tools?"

"Why the blacksmith, of course," replied the surprised mason.

"And who made yours?" he turned to the carpenter.

"None other than the blacksmith," the carpenter answered without a moment's hesitation.

"And your spade and pick-axe?" the King addressed the digger.

"But you know perfectly well, King, that they could be made only by the blacksmith."

Then King Solomon rose and went up to an inconspicuous man with traces of smoke on his dark face. He was the blacksmith. The King led him to the centre of the hall.

"This is the main builder of the temple," said the wisest of kings and seated the smith beside himself on the brocaded cushions to treat him to a cup of fine wine.

We have no way of judging if this legend is true, but it is a good illustration to our point: people have attached great importance to iron from time immemorial.

Most likely the first iron that had fallen into man's hands in hoary antiquity had not been of an earthly but of cosmic origin: there was iron in the meteorites hitting the planet. It is for good reason that in some old languages iron is called a "celestial stone". Still even as late as the end of the 18th century scientists barred the mere thought that the Universe could "supply" earth with iron. In 1751 a meteorite fell near the town of Wagram near Vienna. Forty years later Professor Stutz of Vienna wrote: "Imagine that in 1751 even the most enlightened minds of Germany could believe in the fall of a piece of iron from the sky—so scanty

was their knowledge of natural sciences. But today it is unpardonable to believe such tales."

This opinion was shared by the well-known French chemist Lavoisier, who in 1772 expressed his agreement with a number of his colleagues who insisted that "the fall of stones from the sky is physically impossible". In 1790 the French Academy of Sciences even passed a special decision not to even examine reports concerning stones falling to Earth from the sky. The absurdity of the "tales" about celestial visitors was glaringly obvious to those learned men. But the meteorites, unsuspecting and quite ignorant of the harsh ruling of the French Academicians, continued to visit our planet now and then, disturbing the scientific luminaries' peace of mind. More and more facts proving such visits were accumulating and, as they say, facts are stubborn things. In 1803 the French Academy (it just couldn't help it) had to admit that the "celestial stones" did exist and "permitted" them to fall.

Hundreds of thousands of tons of meteoritic substance containing up to 90 per cent of iron hit the surface of the Earth every year. One of the heaviest iron meteorite ever found is the "Hoba" meteorite which fell in ancient times at what today is Hoba West in Africa. It weighs about 60 tons. In 1896 the well-known American polar explorer Robert Perry found in the ice of Greenland an iron meteorite weighing 33 tons. His find was shipped to New York with tremendous difficulties and is still kept there.

But history knows cases where our planet met with space voyagers that weighed immeasurably more. In 1891 a great crater, 1200 metres in diameter and 175 metres deep, was discovered in the Arizona desert. It had been formed by a gigantic iron meteorite which had hit the surface in prehistoric times.



At one time Americans showed the liveliest interest in the meteorite, especially because there were rumours that the meteoritic splinters contained platinum. Even a shareholder company was set up to organize industrial exploitation of the meteorite. However, it proved difficult to profit by the "celestial gift": the diamond drill broke as soon as it touched the core of the meteorite which was at a depth of 420 metres and the "meteorite" proprietors, having found no platinum in the drilled samples, closed their enterprise. According to scientists, the Arizona meteorite weighed several tens of thousands of tons. Very likely, metallurgists will take an interest in it once more some day.

Meteoritic iron was comparatively easy to work and people learned to manufacture primitive tools from it. But alas, meteorites did not fall on order and the need in iron was growing. Attempts were made to extract it from ores, and finally the time came when the Bronze Age gave way to the Iron Age.

Iron is one of the most widely-distributed elements on earth: the earth's crust

contains nearly 5 per cent of it, or 755 000 000 000 000 tons. But it is only something like a fortieth part of this amount that is accumulated in deposits fit for development. The main iron ore minerals are magnetite, iron stone, brown hematite and siderite. Magnetite contains up to 72 per cent of iron, and as its name suggests, possesses magnetic properties. Red hematite has nearly 70 per cent of iron and its name is derived from the Greek "haima" meaning "blood". Some scientists believe that the word "zhelezo" (the Russian for iron) comes from the Sanscrit "jalja" which means "metal" or "ore". Others suppose that it is based on the Sanscrit "jel" which means "to shine", "to blaze".

A curious technique of searching for iron was used in old times. For this purpose prospectors equipped themselves with "divining" rods—light walnut rods forked at one end. The "geologist" set out on his way holding the ends of the fork in both hands and if he wanted to be successful, he had to observe the "technological instruction" which said that his fingers should point to the sky all the time. Most likely, all "geological" failures in those days (and there were more failures than successes) were blamed on violations of the "technology" of the search. But when all the conditions were observed success was guaranteed and the moment the "geologist" came upon an iron vein, the rod was supposed to dip, immediately indicating the place where ore was situated.

But even in those times there were quite a few people who realized how primitive that "technique" was. The well-known 16th-century German metallurgist and author of the first work on metallurgy, Georg Agricola, wrote: "A genuine miner, in whom we would like to see a sound and serious person, will not use a magic wand, for a sensible person more or less familiar with the nature of things must realize that the fork will do him no good in this

matter, but that he has at his disposal certain natural indications of ore and this is what should guide him." For many years after that, however, the search for ore (for example in the Urals) was often conducted by means of the forked rod. The believers in the rod were ridiculed by the famous Russian scientist Mikhail Lomonosov who wrote: "To my mind, it is better to ignore such pretenders or more correctly, swindlers."

The Moscow state began to experience an acute need in iron as early as the 17th century. Tsar Alexey Mikhailovich sent expedition after expedition to look for new deposits of iron ore. The prospectors were to find out "where and what ore turns up" and determine "how much of it to expect, how it lies and whether it can be hoped to be lasting". But the expeditions were fruitless.

During the very first years of his reign Peter I issued an order "to search for ways to augment any forged and cast iron, to understand the making of foreign (Swedish—S.V.) iron so that it would be possible for Russian people to learn this trade and put it on firm feet in the State of Moscow." Those who would attempt to conceal the discovered ores, Peter's decree said, would be subject to "severe anger, corporal punishment and death".

Soon a message arrived from the Urals saying that rich deposits of the "magnetic stone" were discovered at Mount Vysokaya. The message said: "...Half-way up the mountain slope there is a bulge of pure magnet, around it are dark forests and rocky mountains..." The ore samples that had been sent to Moscow were praised highly by specialists and the tsar ordered the immediate construction of metallurgical plants. He turned one of the biggest works in the Urals—the Nevsky Works—over to the outstanding Tula master iron worker and mill owner Nikita Demidovich Antufyev (who subsequently took the name Demidov) and set him the



task of putting an end to Russia's import of iron. The works was to start the production of "cannon, mortars, muskets, swords, sabres, cutlasses, lances, armour, helmets, and wire".

There is a story about how Peter I became acquainted with Nikita Antufyev-Demidov. One day the tsar who was on his way to Azov stopped over in Tula. He commanded that an experienced armourer be sent in to mend a foreign-made pistol. Nikita Antufyev took the job and by next morning the tsar had his pistol back, ready for use. Peter was surprised that his order was fulfilled so quickly. "But we are no worse than the foreigners," the armourer answered. The tsar took his words for mere boasting. He flew into a rage and slapped the armourer in the face. But Nikita was not confused at all and said, "And you, tsar, would do much better if you first saw what was what and then began to fight.", saying this he drew the pistol the tsar had ordered to be mended out of his pocket.

What happened was that Demidov had made a pistol overnight exactly like the foreign one and his work was so perfect that even Peter's trained eye failed to notice the substitute. The tsar was flabber-

gasted. He forgot his anger and the Tula armourer became one of the people closest to him. Soon after that, on learning that the Neviansky Works was not coping with its military order, Peter put Antufyev-Demidov at its head.

Nikita Demidov and later his son, Akinfy Demidov, did much for the development of national metallurgy. The Ural iron came to be highly valued in the international market. The British newspaper *Morning Post* wrote in the middle of the last century that the Demidov iron "plays an important role in the history of our national industry; it was imported for the first time into Great Britain for conversion to steel at the beginning of the 18th century when our steel-making industry was just starting out. The Demidov iron has greatly contributed to the fame of Sheffield commodities."

Great importance was attached to the quality of iron and ironware since time immemorial. It is said that in the old days when an armourer fulfilled an order for an iron shirt of mail, he first put it on himself and his client dealt him a few blows with his sword. If the craftsman survived, his "product" was considered satisfactory and he was paid handsomely. But if the armourer's work was not good enough, there was no one to pay the money to.

The first government decrees concerning the quality of iron were issued in Peter I's time. On April 6, 1722, the Berg-Collegium (Mining Department) issued an *ukase* entitled "On the Testing of Iron". This prototype of modern steel standards said:

"His Imperial Majesty decrees that this *ukase* should be directed from the Berg-Collegium to all the iron works where iron is made, so that from this time on iron should be tested by the method herewith and that it should be delivered to the places indicated and should be sold bearing the following stamps:

"First test: dig round pillars, 10.5 inches in diameter, into the ground deep enough

for them to be firm and immovable; bore holes through them wide enough for the iron strips to fit in; push the iron through the hole and wind it round the pillar three times; then unwind it and if it does not break and does not show signs of breaking put No. 1 over the factory stamp.

"Second test: take iron strips and strike the anvil three times with them, then take them by the other end and strike again three times, as hard as possible; put No. 2 stamp over the factory stamp on every strip that turns out hard enough to endure the test without showing signs of breaking.

"On the remaining strips, those that will not withstand the above two tests, put No. 3 stamp over the factory stamp.

"From now on no iron strip without the test stamps can be sold."

Severe punishment awaited bad workers. One of Peter's decrees said: "I command that the owner of the Tula Armoury, Kornila Beloglazov, be whipped and exiled to labour in a monastery, for he, scoundrel, was impudent enough to sell His Majesty's army bad arquebuses and muskets. Foreman Frol Fook is whipped and exiled to Azov, let him know better than putting stamps on bad muskets."

In 1737 Stepan Chumpin, a local Mansi, found a sizable lump of lodestone near Mount Blagodat in the Urals and showed it to I. Yartsev, a mining engineer. Yartsev's interest was aroused. He went out to the mountain, examined the place where the stone had been found and hurried to Yekaterinburg to report on the discovery of a new deposit. By that time Demidov had become an uncrowned king of the Urals. On learning about Yartsev's departure, he immediately sent an armed party in pursuit: he was determined not to let the state take possession of the newly-discovered wealth of Mount Blagodat and have it for himself. But Yartsev managed to escape and the Berg-Collegium rewarded the discoverers with a bonus. Soon after that Stepan Chumpin was murdered under

mysterious circumstances and his killer was not found: the Demidovs knew how to deal with people who stood in their way.

The break of the 19th century was marked by a virtual intrusion of iron into technology: in 1778 the first iron bridge was built; in 1788 the first iron water lines were laid; and in 1818 the first iron ship was launched. Fifty years later, in November 1868, a London journal wrote: "The world's first iron ship, the *Volcano*, built in 1818 is under repairs in Greenock. Fifty years ago when she was just leaving the building slips, crowds had gathered to see the miracle—could a ship built from iron really hold herself on water?" Four years later, in 1822, the first iron ship built in England had already been cruising between London and Paris. Railways became a major consumer of iron. The first railroad was commissioned in Britain in 1825.

In 1889 the construction of a magnificent iron tower designed by the outstanding French engineer Gustav Eiffel was completed in Paris. Many of Eiffel's contemporaries thought that his 300-metre latticed structure would prove too fragile to last. Eiffel argued that his creation would stand at least for a quarter of a century. But now, 80 years later, Eiffel's Tower—the true symbol of Paris—is still intact and still attracting crowds of tourists. True, in 1928 several American newspapers carried a report claiming that it had rusted through and was threatening to collapse. But a study of the state of the construction made by a commission of French scientists and engineers showed that the report was a typical canard: covered with a thick coat of paint, the iron was solid.

But it must be said that the peril of rusting always hangs like the Sword of Damocles over iron structures and manufactured goods. Rust or corrosion is the iron's mortal enemy. There are data





supported by a number of scientists indicating that only during the period between 1820 and 1923, 718 million out of a total of 1766 million tons of iron produced in the world, that is almost a half, was "devoured" by corrosion. The loss to corrosion in Britain, for instance, comes to something like 600 million pounds a year.

Small wonder, therefore, that people began to ponder over the problem of corrosion even back in antiquity. Mention of a tin coating on iron articles to protect them from rusting is found in the works of the Greek historian Herodotus (5th cent. BC). A society to combat corrosion has been in existence in India for about 1600 years. Some 1500 years ago it took part in the construction of the Sun Palaces along the coast of Kanerak. Although subsequently the palaces were flooded by the sea and had been underwater for some time, their iron beams had remained in a fine condition. This means that even in early days Indian craftsmen knew how to handle corrosion. This fact is also confirmed by the existence of the famous iron column, one of the most remarkable sights of interest in the Indian capital. This is what Jawaharlal Nehru writes in his book *The Discovery of India*: "Apparently

ancient India had made great progress in the working of iron. Near Delhi there towers a great iron pillar which baffles contemporary scientists. They cannot determine the method of manufacture which prevented the iron from oxidation and other atmospheric hazards."¹

It seems that scientists attributing the mystery of the column to the extremely high skill of ancient metallurgists are perfectly right. In old times India was famous for its steel goods throughout the world, and it was not for nothing that Persians had a saying "to take steel to India" which was synonymous with the Russian "take one's own samovar to Tula" (Tula is a city in Russia which used to be famous for its samovars).

Today one is not likely to be impressed by common stainless steel, but progress continues. Not long ago a patent for transparent stainless steel was issued in the United States. This new metal is made by an electrochemical process whereby tiny pores are created between crystals making steel transparent.

Modern steelmakers have mastered the smelting of numerous metals of most diverse applications to perfection. The number of steels one comes across in the lists of products turned out by a present-day steel works is truly amazing: stainless and high-speed steels, ball-bearing steel, spring steel, magnetic and non-magnetic steels, high-temperature and cold-resistant steels. It would take quite a few pages just to enumerate all of them. For the machining of super-hard materials, for example, extra-hard ("diamond") steel with about 5 per cent of tungsten is used. Tungsten is just a little inferior to the diamond itself in hardness.

A steel works in Belgium commissioned a mill a few years ago for the rolling of steel strip with embossed ornaments. It can

¹ Retrtranslated from the Russian.

be made to look like wood, leather, fabric or some other material. The strip has been enthusiastically received by architects, car makers and manufacturers of household durables.

The assortment of goods made from iron and steel is vast. In the German Democratic Republic, for one, they have built a bearing weighing 125 tons, while makers in Switzerland produce "mini" bearings with a diameter a little over one millimetre. A match box can serve as a container for 34 000 such bearings. The steel parts for some watches are even smaller and the "mini" bearings can consider themselves bulky in comparison: a match box will hold up to 6 000 000 of them.

The demand for iron is great. Suffice it to say that by the end of the 19th century 96 out of every 100 kilograms of metal consumed by industry, agriculture and everyday life was iron.

Town building and railroad laying, the launching of ocean-going boats and the construction of giant blast furnaces, the development of powerful synchrotrons and the launching of space

ships—none would be possible without iron.

But iron has not always served the purposes of creation. Many blood-drained pages of history are associated with it. During the First and Second World Wars iron was used to shower people with thousands of millions of shells and bombs. It was used to destroy what had been created from iron with the help of iron.

Almost two millennia ago the ancient Roman writer and scientist Pliny the Elder wrote: "Iron mines bring man a most splendid and most harmful tool. It is by means of this tool that we cut into the ground, plant bushes, cultivate flourishing orchards and make grape vines younger every year by cutting off wild vines with grapes. By this same tool we build houses, break stones and use iron for all such purposes. But it is also with the help of iron that we fight and battle and rob. And we do it not only at close quarters, but, giving it wings, we hurl it far into the distance, now from embrasures, now from powerful human hands, now from bows in the form of feathered darts. This, I think, is the most infamous invention of the human



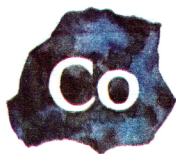
brain. For in order to enable death to catch up with man faster, it has given it wings and armed iron with feathers. For that may the blame rest with man and not with Nature." Let us not blame iron for our sins, either.

During the last few decades iron has acquired many rivals: aluminium, titanium, vanadium, beryllium, zirconium and other metals and they are all on a massive offensive against iron's position. But despite its venerable "pension" age (more than 5 000 years), iron shows no sign of wishing to "quit" its job. Academician Fersman wrote: "The future belongs to other metals. Iron will occupy the honourable position of an old, merited

material which has done its bit. But this future is still very remote. So far iron remains the basis of metallurgy, mechanical engineering, communications, ship- and bridge-building and transport".

... In 1958 the unique *Atomium* building was erected on the territory of the World's Industrial Fair in Brussels. It consisted of 9 great metal spheres each 18 metres in diameter. They gave the impression of being suspended in the air: 8 in the apexes of a cube and the ninth in the middle. That was a model of the iron crystal lattice magnified 165 000 million times. The *Atomium* symbolized the grandeur of iron, the great toiler and the main metal of industry.

THE CHARGE OF THE GUNS OF PEACE



Paracelsus' trick.—Blue china.—The strange ores of Saxony.—Brandt gives a dissertation.—A veterinary doctor's hobby.—Every cloud has a silver lining.—The Heynes Firm's novelty.—Japanese steel.—Treachorous "toys".—Damage to the British Fleet.—The surprise of the old dump heap.—In alliance with platinum.—Stronger and cheaper.—The discovery of the great couple.—Like a fairy-tale genie.—The "cans" are tested.—The professions of radioactive cobalt.—Pharaoh's mask.—Blue diamonds.—How is one to catch lightning?—Doctor's assistant.

It is said that the well-known 16th century chemist and doctor Paracelsus liked to demonstrate a trick which was invariably successful. He would first show his audience a painting of a winter landscape—snow-covered trees and hills. After letting them admire it as long as they pleased, he would turn winter into summer before their very eyes: the trees would cover with foliage and the white hills would disappear beneath new green grass.

Was it a miracle? But we know that there are no miracles in this world. The magician in that experiment was chemistry. At room temperature a solution of cobalt chloride containing a quantity of nickel or iron chloride is colourless. But if it is used to draw something, then warmed up even a little bit after it is dry, it becomes beautiful green in colour. It was this kind of a solution that Paracelsus had applied to his magic canvas. At a certain moment the scientist, unobserved by the people in the audience, would light a candle behind the canvas and the amazing change of season would set in.

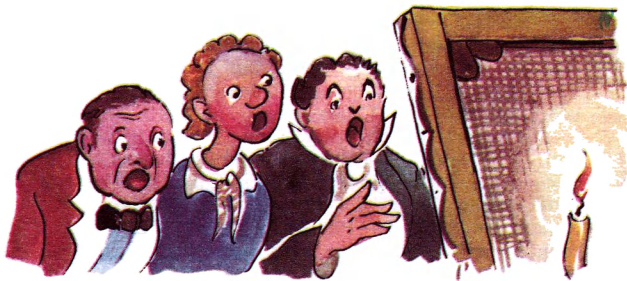
True, Paracelsus himself could not say what was the exact chemical composition of his paints: neither cobalt nor nickel were known to science yet. Meanwhile cobalt compounds had been in use as

pigments for several centuries by then. Even 5000 years ago a blue cobalt pigment was known in ceramics and glass making, while in China it was used in the manufacture of the famous blue china. Ancient Egyptians covered earthen pots with a blue cobalt-containing glaze. In King Tutankhamen's tomb archaeologists found glass stained blue with salts of cobalt. Glass of the same origin was also discovered in excavation sites in ancient Assyria and Babylonia.

It seems that the secret of preparation of cobalt paints had been lost somewhere at the beginning of our era, since the blue glass dating to that period made by masters in Byzantine, Alexandria and Rome had no cobalt and the blue colour which was achieved by introduction of copper was clearly inferior to the ancient blue pigment.

The "separation" of glass from cobalt lasted for a long time: it was only in the Middle Ages that glass-makers in Venice began to turn out the wonderful blue glass which had soon won popularity in many countries. And it was again cobalt to which the glass owed its fame.

The Venetian craftsmen vigilantly guarded the secret of their glass which was of unsurpassed beauty. To reduce the



possibility of any "information leak", in the 18th century the government of Venice transferred all glass factories to the small island of Murano which no outsider was permitted to visit. Neither were the glass-makers themselves allowed to leave the island without permission of the authorities. Still there was one Giorgio Belerino, an apprentice, who managed to flee from the island and make it as far as Germany. There he opened his own glass-shop. The shop did not last long, though. One day a fire "occurred", the shop burned down and the fugitive owner was found stabbed with a dagger.

According to surviving 17th century documents, in Russia there was a great demand for the expensive, very stable and rich cobalt paint which was called "golubets" (in Russian the word "goluboy" means "blue"). This paint was used for the wall paintings in the Faceted Hall, the Armoury, the Archangel Michael and the Dormition Cathedrals in the Kremlin and in other magnificent edifices of that period.

The expensiveness of cobalt paints was to be explained by the very small production of cobalt ores. True, it would be more correct to say that industry simply had no idea of cobalt ores, since no sizable accumulations of this element exist in nature. Cobalt only accompanies in fairly small amounts such elements as arsenic, copper, bismuth and some others. That was why miners in medieval Saxony had not suspected that their mountains were rich in rock containing an unknown metal. Every now and then they would come across a mysterious ore that possessed the outward characteristics of silver ore, but they invariably failed in all their attempts to produce silver from it. Furthermore, when that ore was roasted it released poisonous gases that were extremely troublesome to the miners. Finally they did learn how to distinguish between genuine silver ore and its

deceptive replica. They began to call it "cobold" after the mountain spirit whose "adobe" the ore was.

In 1735 the Swedish chemist G. Brandt analyzed some ores of Saxony, including the notorious "cobold", and on the basis of the material he obtained, gave a dissertation proving that the ores contained a then unknown metal. Brandt named the new metal after the ore "cobold". Had this discovery been made in our days, the teletypes would have spread the news throughout the world immediately. But no such thing was possible in the 18th century, and for years the Swedish chemist's dissertation was known only to a select few. Even thirty years after that some scientists, among them Leman in St. Petersburg, believed "cobold" to be a mixture of copper, iron and some "special earth".

It was only at the end of the 18th century that the efforts of many scientists, including the Russian chemist G. I. Guess, brought about the confirmation and formalization of Brandt's discovery, and the metal he had found was given the name that we have always used—cobalt.

By that time the closest chemical relative of cobalt, nickel, had already been discovered. These metals often went together in nature and it was for good reason that scientists had to face the question of how to separate them and obtain each in pure form.

The answer to that most complicated chemical problem was found quite unexpectedly by ... a veterinary doctor Charles Askin. This is how it happened. The veterinarian devoted all his free time to his hobby, metallurgy. In 1834 he became interested in nickel and its alloys. Askin attempted to extract nickel from ore. But unfortunately (or rather fortunately) the ore with which he was working also had cobalt in it. Askin did not know what to do about cobalt and turned for advice to Benson, the owner of a local chemical

plant. As it turned out, Benson was in need of cobalt which he used in the manufacture of ceramics. But Benson did not know any way of separating the two metals. After some thinking the researchers decided to try chlorinated lime and made a careful calculation of the amount they would need. Each set to work separately.

Benson had enough chlorinated lime. He measured out the necessary quantity, tried it on the ore, but luck was not with him: his solution contained a deposit of the oxides of both metals.

Meanwhile Askin had discovered that the chlorinated lime at his disposal was only half of the calculated amount. "This is my hard luck," Askin must have thought to himself. Nevertheless, he decided to go on with the experiment. But as they say, every cloud has a silver lining. To Askin's amazement and joy, the experiment which had seemed so unpromising, gave the desired result: cobalt had precipitated in the form of oxide and nickel, for which there had not been enough chlorinated lime, had almost wholly remained in solution. Subsequently Askin's method was somewhat improved and has been widely

used in industry ever since to separate chemically-related metals.

Cobalt's sphere of action had remained extremely limited until the beginning of the 20th century. Metallurgists, for example, who treat cobalt with such respect today, had a very vague idea about its properties. A book published in 1912 by Ye. Pro on the metallurgy of nonferrous metals asserted that "... until now metallic cobalt has not presented any interest from the standpoint of industry. There were attempts to introduce cobalt in iron and prepare special steels, but the latter have still found no application."

The esteemed author was mistaken. Even five years before his book was published the Heynes firm had produced new alloys characterized by great hardness and intended for metalworking. One of the best of the new alloys which were named stellites (from the Latin "stella"—star) contained more than 50 per cent of cobalt. After that the production of hard alloys was steadily growing, with cobalt playing an important role in them.

Soviet scientists and engineers developed the super-hard *pobedit*, an alloy which was superior to foreign analogous alloys. Apart from tungsten carbide, it also contained cobalt.

In 1917 the Japanese scientists Honda and Takati obtained a patent for a steel which contained from 20 to 60 per cent of cobalt and possessed high magnetic properties. The need in this steel which came to be known as Japanese, was great. The end of the 19th and the beginning of the 20th centuries were characterized by a virtual intrusion of magnetic materials in industry, hence the acute magnetic steel "hunger".

Of the three ferromagnetic metals—iron, nickel and cobalt—cobalt possesses the highest Curie point, i.e. the temperature at which a metal ceases to be magnetic. Whereas for nickel the Curie point is as low as 358°C and for iron it is



770°C, for cobalt it is 1130°C. Since magnets have to work in most varied conditions, very high temperatures included, cobalt was destined to become the principal component of magnetic steels.

Hardly had cobalt steel been developed, than it became the focus of attention of military and industrial bosses who had rightly guessed that they could have their own (alas, not at all harmless) use for its special properties. Even during the Civil War in Russia (1918-1920) sailors and Red Army men came across unusual mines on which minesweepers of the Northern Dvina Flotilla got blown up, never having even touched them. When divers managed to get hold of one of those sinister "toys" and defuse it was found that it was magnetic. The principle on which it operated was that as soon as the steel hull of a ship turned up in the magnetic field of the mine it was immediately detonated and the ship sank.

On the eve of the Second World War the production of cobalt steels used for the manufacture of magnetic mines had gone up considerably in Nazi Germany. Goebbels' propaganda asserted that in precision, sensitivity and speed of reaction the German mines were "superior to the nervous system of many higher beings brought forth by the Creator". Indeed, when the Germans had managed to mine the coast of England and the mouths of the Thames and other principal rivers from the air, the damage done to the British Fleet by the magnetic mines was heavy. But every poison has its antidote. Only two weeks after Germany's treacherous attack on the Soviet Union, M. I. Ivanov, military engineer 3rd rank, working near Ochakov on the Black Sea defused the first German magnetic mine.

A remarkable incident took place at an ore mine in the Urals also during the war. Cobalt of which no one had suspected was discovered in old tailing heaps of an ore dressing factory which had been processing



copper ore for many years by then. Within a short period of time a process of cobalt extraction was developed and the defence industry was supplied with a most valuable metal mined from "barren" rock.

During the war cobalt began to be included in heat-resistant steels and alloys from which parts of aircraft engines are made, missiles, high-pressure steam boilers and turbocompressor and gas turbine blades. One of those alloys is vitallium which contains up to 65 per cent of cobalt. But the short supply of cobalt and its high price are the factors holding back what would have been even a more extensive application of it in metallurgy.

There are spheres, however, where cobalt successfully replaces platinum which is an even more expensive metal and the yearly production of which is easily loaded onto one truck. Electrolytic metallurgy cannot do without insoluble anodes i.e. anodes that will not react with the electrolyte. Platinum is a very good metal there, but it is too expensive. The question of replacing platinum with a cheaper metal has intrigued scientists for a long time. A meticulous search has enabled them to develop an alloy which is in no way inferior to platinum, and moreover, is even better in its ability to withstand aggressive acids. This alloy contains up to 75 per cent of cobalt.

In some cases a combination of cobalt with platinum is used. The British firm Mulard has created a magnetic alloy of these metals which has high corrosion resistance and easily yields to machining. It is used in miniature magnetic parts for electric watches, hearing aids and data units.

An alloy of cobalt and chromium has been proved an excellent material for dental fixtures. It is twice as strong as gold and much cheaper, naturally.

So far we have been discussing ordinary cobalt, but it must be said that since 1934 when the outstanding French scientists

Frederic and Irene Joliot-Curie discovered the phenomenon of artificial radioactivity, science and engineering have shown a lively interest in the radioactive isotopes of various elements, including cobalt. Of the 12 isotopes of this element cobalt-60 has found the widest application. Its rays have a high penetrating ability. In power of radiation 17 grams of radioactive cobalt are equivalent to one kilogram of radium, nature's most powerful source of radiation. This is why when this isotope is produced, stored and transported (just as in the case of other isotopes) the strictest safety measures are taken to protect people from the lethal rays.

After ordinary metallic cobalt is turned into radioactive cobalt it is "bottled up" like a genie in special containers resembling common milk cans. In these containers coated with a layer of lead, cobalt-60 is taken by special vehicles to the place of its future work. But what if the vehicle gets into a road accident, will it mean that the ampule with cobalt will break and threaten human lives? No, this is out of the question. True, there is no automobile that can be guaranteed against an accident. But even if it does happen, the "can" will remain intact: it is subjected to the severest tests before it is allowed to receive its deathly charge. Such cans are dropped from a height of 5 metres onto concrete slabs, placed in thermochambers and put through other such trials. It is only then that they are allowed to carry the little ampule. These and other measures reliably protect people who work with radioactive sources.

Radioactive cobalt has many "professions". Most widely used in industry, for example, is flaw detection by gamma rays, that is, control over the quality of production by means of gamma-radiography. The gamma source in it is cobalt-60. This method involving relatively inexpensive and compact equipment makes it possible easily to detect cracks, pores,

airholes, and flaws in massive casts, weld seams, units and components situated in places difficult of access. The fact that the gamma rays are distributed by the source evenly in all directions enables the operator to inspect a large number of objects simultaneously and those shaped like cylinders, simultaneously along the entire perimeter.

Gamma rays have enabled Egyptologists to clear up one mystery which has intrigued them for a long time now. Some of them asserted that Tutankhamen's mask was made from a solid piece of gold, while others argued that it consisted from several gold parts. They decided to use a cobalt gun—a special installation “charged” with cobalt-60. It was established that the mask indeed consisted of several parts, but that their fit was so perfect it was absolutely impossible to detect the joints.

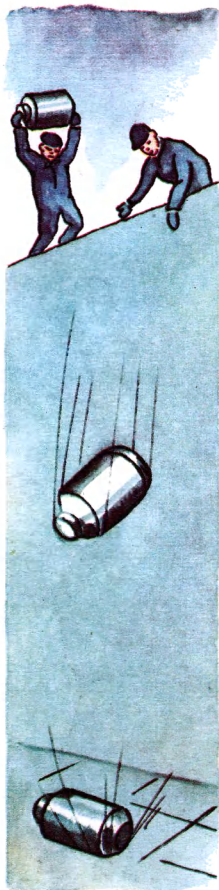
Radioactive cobalt is used to control the level of molten metal in smelting furnaces and the level of the charge in blast furnaces and bunkers, as well as to maintain the level of liquid steel in the crystallizers of continuous-pouring installations.

There is a special instrument to measure the thickness of skin-plating of hulls, walls of pipes, steam boilers, etc. which cannot be reached from the inside by standard instruments.

The so-called labeled atoms, i.e. radioactive isotopes of a number of elements, including cobalt, find extensive use in the study of technological processes and operating conditions of various equipment.

For the first time in world experience scientists and engineers in the Soviet Union have built a commercial radiation-and-chemical reactor in which the source of gamma rays is also furnished by cobalt-60.

Along with the modern methods of treatment of various substances—super-





high pressures, ultra-sound, laser radiation and plasma treatment—radiation methods are being introduced in industry on a large scale, making it possible to significantly improve the quality of many materials. For example, radiovulcanized tires, have a 10-15-per-cent longer service life, while the fabric for school uniforms into which polystyrene molecules have been “grafted” by means of radiation is twice as durable. Even gems become more beautiful after “radio treatment”: the diamond irradiated by fast neutrons acquires a blue tinge, slow neutrons make it green while the cobalt-60 rays give it a soft bluish-green colour. Radioactive cobalt is also employed in agriculture to determine the earth’s moisture content, estimate the water reserves of snow, irradiate seeds before sowing, etc.

Not long ago French scientists discovered that radioactive cobalt could be effectively used to capture ... lightning. A small addition of the isotope to the material from which the lightning rod is made causes gamma rays to ionize considerable volumes of the air around it. The electrical discharges in the atmosphere are then attracted to the radioactive lightning rod as though by a magnet. The rod “collects” lightning within a radius of several hundred metres.

Today radioactive cobalt is the doctor’s reliable aide in the battle for people’s lives. Grains of the isotope cobalt-60 placed in medical “guns” bombard internal malignant growths without doing any harm to the organism, but damaging the fast-growing sick cells, halting their activity and thus eliminating the foci of the sinister disease.

In the underground storage rooms of the USSR Isotope organization there are kept dozens of containers, big and small, with cobalt, strontium, cesium and other radioactive substances. When time comes they are sent to hospitals and clinics, factories and research institutions where atoms are used for peace.

“COPPER DEVIL”



Great-grandmothers' joy.—An ancient alloy from China.—The evil spirit's tricks.—No coward.—An energetic Frenchman.—A find in Canada.—Rzheshtarsky's gold metal.—“The Worker and the Woman-Collective Farmer”.—An “epidemy” and its cause.—Who is to blame for the Emperor's death? —“Subversive activities” in the navy.—Three thousand in service.—The past will not be forgotten.—Shiny and bright.—A “sandwich” coin.—Pearl from fat.—A razor is going to the Moon.—Anything to be done about hay fever? —“Nepotism” and worries.—Close ties.—Nickel-plated planet.—Fox-terrier looking for ore.—“Mammoth explosion”.—Get a star from the sky.—Daring plans.—Will justice be restored?

Probably not many women know that in the old days when their great-grandmothers were young charming ladies they loved nickel and it looked good on their necks, wrists and hair. And small wonder: even as late as the beginning of the 20th century nickel was considered a precious metal. Its extraction was extremely involved and the minute amounts of it that were obtained ended up in jewellers' shops. Not that engineers were showing any interest in this metal: no use for it had been invented yet.

It is likely that people learned about nickel many ages ago. It is a fact, for example, that back in the 2nd century B. C. Chinese made an alloy of nickel with copper and zinc which was called packfong and was in demand in many countries. It even got to Bactria, the state which was situated on the territory of what today is Soviet Central Asia. Bactrians made coins from it. One of them made in 235 B.C. is kept in the British Museum in London.

The element nickel was discovered by the Swedish mineralogist and chemist Cronstedt in 1751 in the mineral niccolite. But in those times this mineral was called "kupfernickel" ("copper devil"), and there is a story to explain it. Back in the Middle Ages Saxon miners often came across

a reddish mineral which they mistook for copper ore. For a long time they made repeated attempts to smelt copper from it, but their chances were as slim as those of the alchemists who tried to produce gold from animal urine by means of the "philosopher's stone".

Saxons racked their brains over what could be the reason for their failure. Finally, it dawned upon one of them: it must be Nick, the evil spirit of the mountains, at his tricks. He must have "entrenched" himself in the accursed stone and was determined not to let a single ounce of copper out of his clutches.

Probably, the medieval men of science did manage to substantiate their bold hypothesis. At any rate, no more attempts to get copper from the reddish mineral were made. It was decided to give it the name "copper devil" so that no one would get the bright idea of doing anything with it.

Evidently Cronstedt was not superstitious. He was not afraid of the devil and obtained a metal from kupfernickel. It was not copper, however, but a new element which he called nickel.

Another fifty years had passed and the German chemist Richter was able to extract relatively pure nickel from the ore. It was a silvery-white metal with a barely discernible brown tinge which was highly malleable and ductile. But there could be no talk of commercial nickel production yet.

In 1865 big deposits of nickel ores were discovered in New Caledonia. Not long before that Jules Garnier, a person of enormous energy and vast education, was put at the head of the mining department of that French colony. Garnier immediately launched a feverish activity in search of minerals. He was successful and soon it was discovered that the island was rich in nickel ore. In honour of the energetic geologist the New Caledonian mineral was given the name garnierite.



In Canada, nearly twenty years later, workers on the construction of the Pacific Railway stumbled upon tremendous reserves of copper-nickel ores.

The two discoveries gave a powerful impetus to the beginning of the commercial production of nickel. At about the same time metallurgists discovered nickel's important ability to improve the quality of steel. True, as early as 1820 the famous English chemist and natural philosopher Michael Faraday carried out several experiments in making nickel-containing steels, but failed to interest the steelmakers.

At the end of the last century the Obukhov plant in St. Petersburg was given an important Naval Department assignment: to develop a process for the manufacture of high-quality ship armour plate. By that time the British and French navies had already been coated in new armour made from nickel steel which had been highly praised by specialists.

The development of the new steel was undertaken by the noted Russian metallurgist A. A. Rzheshtarsky. Shortly afterwards his intense efforts were crowned with success. The Obukhov plant started manufacturing excellent 10-inch armour plate from nickel steel. The Obukhov armour plate was in no way inferior to the foreign but Rzheshtarsky wanted it to be still better. After a while he was able to launch a new process of making steel armour, whereby the external layer of the metal was cemented, that is, saturated with carbon. The new metal was exceedingly strong and ductile and with an extra-hard external layer. Even the armour plate turned out by the French Schneider-Creusot concern, which had always been considered the highest standard, could hardly compete with it.

The Russian Naval Department awarded the talented metallurgist a gold medal and his process was introduced at other works is well.

In our days nickel steel is used for peaceful ends. Manufactured from it are surgical instruments, components for chemical facilities and household items.

Recall the magnificent sculpture of the outstanding Soviet sculptress Vera Mukhina, "The Worker and the Woman-Collective Farmer". This 24-metre monument made from stainless steel with an addition of about 10 per cent of nickel was put up at the World's Fair in Paris and is today towering at the entrance to the USSR Economic Exhibition in Moscow.

Nickel is very important in a wide range of alloys with other metals. It was yet back in the beginning of the 19th century that metallurgists and chemists fell victim to what became a virtual "epidemy"—an overall search for a new alloy to replace silver completely in the making of table sets. The "epidemy" had been caused by a handsome bonus that was promised to the one who would be lucky enough to develop such an alloy. That was when they remembered the old Chinese packfong. Almost simultaneously several scientists who took packfong as a base managed to obtain copper-nickel alloys which looked very much like silver. One of them was called "argentan" ("like silver") and another, "neusilber" ("new silver"). They were followed by melchior, alfenid and other types of nickel (or German) silver.

Within a short period of time nickel alloys had become very popular and very much in demand. But in 1916 one of the new alloys, neusilber, became ill-famed: Francis Joseph, Emperor of Austria-Hungary, who had a table set made from it, had suddenly fallen ill and died. The set from "new silver" became the main suspect and the use of it was banned. Meticulous research, however, fully proved the alloy's innocence. As to the Emperor, his death was not so sudden after all: he was 86.

Nickel alloys were found more and more things to do. For example, they did

a service to warships. During the First World War there were several cases where warships which had not even been engaged in military actions were sent to docks for lengthy repairs. That was the result of the "subversive" activity of seawater which literally ate up the copper-zinc alloy condenser tubes in ship boilers. A more suitable material had to be found urgently.

But while researchers were busy looking for such material the war had ended, leaving the question still unsolved. It was only in 1926 that a copper-nickel alloy to which service in the sea was not contraindicated was developed. Three years later all French ships, followed by the navies of other powers, had replaced their condenser tubes. Now seamen could be sure that the notorious tubes would not let them down at a time of trial. At present the number of nickel alloys that have found the widest applications in technology, everyday life and jewelry has topped 3000!

For example Monel metal is important to chemical engineering and shipbuilding; nichrome coils are used in electric heaters and electric resistance furnaces; neusilber goes into various instruments and apparatus, invar, an alloy characterized by a very low expansion coefficient (heated from 0° to 40°C its volume expands by only one-millionth), is used in precision

instrument making for the manufacture of gauges and standards, platynite replaces expensive platinum where it is necessary to seal metal in glass (syringes, electric lamps, etc.), and the resilient elinvar is excellent for springs, especially watch springs. The alloys mihima, alnico and alni have high magnetic properties. After a special thermo-mechanical treatment permalloy acquires exceptional magnetic permeability and is easily magnetized and demagnetized even in weak fields. It is applied in telephony and in radio engineering. From chromel and alumel thermocouples are manufactured. The turbine blades of the TU-104 airliner engine are made from a nickel-base (up to 75 per cent) alloy.

A new alloy—nicosi—was developed a few years ago. Its name is derived from its three metal components—94 per cent of nickel, 4 per cent of cobalt and 2 per cent of silicon. Tests have shown that nicosi is to play an important part in creating powerful ultrasonic sources.

But of the greatest scientific and commercial interest is nitinol, an alloy of nickel (55 per cent) with titanium which was developed in the United States, in the 1960s. But it was only recently that its special "talent" was discovered. Fairly light, strong, ductile and corrosion-resistant, it has been considered a



good alloy and nothing else. But its creators continued experimenting with it and suddenly it demonstrated a unique ability to "remember" its past. It happened during one of the numerous experiments with the new alloy. After a special treatment a nitinol wire coil was heated to 150°C, then cooled, and then a weight was suspended from its end. The coil stretched out into an absolutely straight wire. The miracle happened when the wire was again heated (to 95°C). Right before the eyes of the dumbfounded researchers it coiled up once more!

The experiment was repeated over and over again, and each time the alloy was given more and more intricate configurations. But still it continued to demonstrate its perfect "memory" and assumed its original form. In one of the experiments the wire was bent to form the word "nitinol". After that it was heated, cooled and deformed past all recognition. But nevertheless the minute a powerful electrical impulse was passed through it warming it up immediately, the researchers were once more able to read the name of the alloy.

No definite explanation to this phenomenon has been found yet, but there have been hundreds of suggestions as to its uses. One of them resulted in the creation of nitinol rivets in structures where they can be reached only from one side. First a standard rivet is made, the shape of which the alloy has to "remember". Then one of its ends is smoothed out into a stem and put through the hole under low temperature. After that the head of the rivet has to be warmed up slightly and it will immediately "remember" that it was supposed to have another head on the other end. A rivet like that fastens the components dead tight.

An American firm concerned with space research has modelled a nitinol antennae intended for artificial earth satellites. Rolled into a tight ball and fitted into

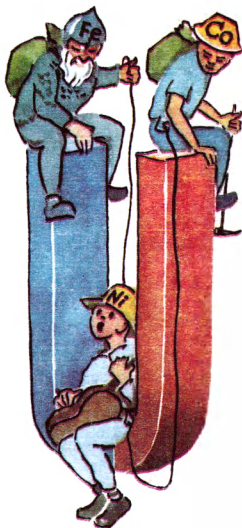
a special recess, such an antennae will not take much room during launching, but when in space, it will be warmed up by sun-rays and will take the necessary form. This principle has also been suggested for the radiotelescope which will have an antennae over one kilometre long.

Nickel offers an excellent protection from oxidation, not to mention that it makes a beautiful finishing on metal objects. The pots and pans and samovars and many other articles of household use owe their shiny appearance to a thin nickel coating.

The first attempt to use nickel as a coating material was made by the German scientist Bether in 1842. He failed, however, since the nickel which was available at the time contained impurities preventing electrolytic nickel-plating. Electrolytic metallurgy has made great progress since then. The thinnest nickel coating that is possible today reliably protects iron from corrosion and saves enormous amounts of this metal.

Nickel has even helped to keep counterfeiters in check. The 5-franc coin which was minted in France not long ago was no ordinary coin but was a "sandwich": its middle was made from the non-magnetic German silver and its external layers were from nickel. Now owners of slot-machines can rest assured: the new coin has such electromagnetic characteristics that it cannot be replaced by any counterfeit.

Scientists and engineers have long since noticed nickel's catalytic properties. In the 1890's the French chemists Sabatier and Senderens became interested in the problem of making so-called "hardened" fats from liquid oils. They established that for this end to be achieved an oil molecule should bond with a definite number of hydrogen molecules. But establishing was one thing and actually achieving it quite another. First the researchers tried to pass hydrogen through the oil, but the gas would not react with it. Next they attempted



to introduce various additions, but again failed. It was only after they had used the finest nickel powder as a catalyst that they succeeded. The fat they obtained was used in the production of margarin which was given this name because of its pearly aspect (in Greek margarón is a pearl).

Among the nickel compounds of special importance is nickel oxide which is used for the manufacture of nickel-iron storage batteries. Being inferior to the lead ones in electromotive force, they nevertheless have several advantages over them: they are lighter, their service life is longer and they are simple to handle.

Not long ago an American firm designed a new razor working on three nickel and cadmium batteries. According to American

mass information media, NASA contemplated the possibility of the new razor being taken to the Moon by the American astronauts.

For years have doctors been puzzling over the causes of the various allergic diseases the incidence of which has continued to grow the world over. One of the latest breakthroughs in medical research in Moldavia has been the discovery that the blood of bronchial asthma, antritis and hay fever patients contains several times more nickel and lead than the blood of healthy people, while the amount of other microelements is roughly the same. This remarkable discovery will help doctors to see into the mechanism of some allergic diseases, making diagnosis easier for them and enabling them to find new and more effective methods of treatment.

In the Periodic Table nickel is situated next to iron and cobalt. Having many properties in common, these elements are sometimes referred to as the iron triad. Curiously enough, out of the 104 elements known to science today only the members of the iron triad are characterized by ferromagnetic properties under ordinary conditions. This "nepotism" is extremely troublesome to metallurgists, as it is not simple at all to separate nickel from cobalt, or from copper, its other neighbour in the Table, for that matter. And in nature nickel is, as a rule, accompanied by cobalt and copper. The separation of these elements is an exceptionally involved, multi-stage process. This is why nickel is considered one of the most expensive and scarce commercial metals.

The earth's crust contains 0.008 per cent of nickel. But do not get the impression that it is little. This percentage stands for 10^{15} tons—the estimated general amount of nickel. Let us imagine for a moment that it has occurred to someone to put a nickel coating over the planet. Will the reserves be enough? A simple calculation

shows that not only are they ample, but that they are enough for 20 000 (!) other such planets. And the earth's crust is just a "shell" beneath which there are layers of far greater density that, scientists believe, must contain considerably more nickel.

It is an interesting fact that in some cases geologists recruit dogs for their prospecting work. For several years now workers at the Institute of Geology of the Karelian Branch of the USSR Academy of Sciences have conducted experiments jointly with the Institute of Mineralogy to train four-legged ore-seekers. Two sheep dogs, a fox-terrier and a Spaniel react like sensitive instruments to many ores, nickel included, lying at a depth of several metres. Today Zeus, Irbit, Dick and Pirate, as the dogs are called, and their many "colleagues" are employed by geological parties whom they help to determine exactly where the wells should be drilled.

"Isn't it too primitive for the 20th century?" our reader is likely to think at this point. But do not jump at conclusions: in northern boggy regions geologists face a tough job looking for minerals, not to mention that it is expensive. But the dogs can reach such places that are absolutely inaccessible for humans. The live "instruments", moreover, cover ten times more ground than is the radius within which common physical instruments used in geological survey are effective. The dogs have one more advantage: in order to "inspect" 20 boxes with specimens they need just a few seconds, while even an experienced geologist will need a whole day and night.

The experience of Soviet geologists has been copied in Canada where three dogs were picked in a Vancouver police department and were trained in the new line. Within only one prospecting season the dogs, guided by experienced geologists, discovered several promising deposits of nickel and copper.

Canada is leading the capitalist countries in the extraction of nickel ores. Several



years ago a major industrial explosion was carried out in the vicinity of Lake Ontario where one of the biggest Canadian deposits is situated. The preparations lasted for more than a year. Seventeen thousand blast-holes were drilled in the rock, their total length measuring a few dozen kilometres. The holes were filled with an enormous amount of explosive, in fact, a train of 30 cars! The mammoth explosion, to use the expression of the Canadian press, raised into the air one and a half million tons of mountain rock and three and a half million tons of nickel ore. Big nickel deposits were discovered quite recently near Lake Manitoba. The "find" was made with the help of the instruments mounted on an artificial earth satellite.

At the end of 1969 the London stock exchange suffered a seizure of unprecedented panic and excitement over the Poseidon nickel stocks. Following news reports from distant Australia, the shares climbed rapidly one moment, dropping catastrophically the next. The Poseidon shareholding society was set up after significant quantities of nickel had been discovered in the coastal sand of Australia. News of every new development in the geological prospecting under way was immediately wi-

red to London. First a fairly high content of nickel in the sand was reported and the price of the shares went up accordingly. Later the report was denied and it was explained that a mistake had been made augmenting the nickel content ten times (the comma in the reported figure was one zero too far to the right). Within just a few minutes the Poseidon shares had dropped and were all but given out free. Then there was news that the initial information on the high nickel content was correct and again the prices skyrocketed. Someone must have made quite a tidy sum out of the panick. At present the "epicentre" of the nickel boom has moved to Australia proper where several dozen mining companies are now competing for the right to exploit the deposits. Unlike here on earth where nickel occurs only in company with other elements, it is reported to exist in pure form on some space objects. Were it possible to get a star from the sky, it would probably prove to possess the isotope nickel-80 (here on earth this isotope exists in the form of five lighter isotopes). The density of terrestrial nickel is 8.9 g/cm^3 , but on the stars where the density of

matter is extremely high (such as on white dwarfs) one cubic centimetre of nickel weighs tons! Interestingly, the mean density of the Universe is less than 10^{-29} grams per cubic centimetre. If that were the density of the earth, then it would have weighed 10 milligrams!

"Space nickel" reaches our planet in substantial quantities. According to Soviet scientists, up to 250 grams of meteoritic nickel hit one square kilometre of the World Ocean every year. It would seem that this amount is not so large. But the ocean is of an advanced age, impressive size, hence it must have impressive "mineral" savings. The latest data obtained by means of artificial earth satellites reveal that the earth's atmosphere absorbs annually over a million tons of interplanetary dust (and it must be borne in mind that during meteoritic showers this "layer of dust" increases hundreds of times) and it is known that the nickel content in it is very high.

There are interesting projects concerned with supplementing earthly reserves of nickel at the expense of space objects. It is known that tens of thousands of the



so-called minor planets are travelling in interplanetary space. They are the asteroids that mainly consist of iron and nickel. Some of them travel along orbits situated close to the earth's and sometimes appear quite close to it. A number of scientists believe that it is theoretically possible by means of rocketry to pull an asteroid onto an orbit close to earth and start the production of iron and nickel on it. One project envisages the sending to the asteroid of special automatic devices which will smelt, by means of solar furnaces, asteroid material into ingots weighing millions of tons each. Rockets will take the ingots to a circumplanetary orbit and they will only have to be brought to the earth's surface. But how? One suggestion is to smelt it on the orbit and inject gas into it, produce blocks of foam metal and then drop them into the ocean where they will

float until transports arrive to take them to coastal metallurgical works. It is estimated that one cubic kilometre of asteroid material at today's rates of nickel consumption will take care of the world's needs in this metal for something like 1 250 years to come.

Daring plans, aren't they? But remember, a very short while ago man's visit to the Moon was believed to be no more than a wild flight of imagination even by many scientists.

Our story about a metal which was named after an evil spirit of the mountains is coming to an end. Who knows, maybe a time will come when justice will be restored and nickel will be renamed after a "kind spirit". But is the name so important after all? Any name is all right as long as the thing by which it goes does people good.

ONE OF THE OLDEST AND CELEBRATED METALS



The treasure of ancient Urals.—Inheriting from the Sinanthropus.—The “magnificent seven”.—The Stone Age is retreating.—On the construction site of the Great Pyramid of Khufu.—The best gift for a woman.—Alchemist priests.—Incantations to cure “sores”.—Achilles’ impregnable shield.—Scrap metal from one of the Wonders of the World.—A night bar in the head.—“Take goat-milk cheese ...”—Circles under the eyes.—Cannon House.—The domes of St. Basil’s Cathedral.—A lucky business trip.—The Church is parting with its bells.—A clever move.—“Copper riot”.—An unusual auction.—The tricks of the copper concentrate.—Blue blood?—The carp should be protected.—“Anti-shark” drug.—Gnomes at work.—Violets prefer zinc.

Boundless are the treasure houses of hoary Urals, hidden deep under the rocks and sparkling with beautiful gems. Probably not one of them figures as prominently in folk tales and legends as malachite. Sung by the Russian writer Bazhov in his *Ural Tales*, this amazing green stone with inimitable patterns of darker and lighter lines was turned by master gem-cutters into articles of matchless beauty. From time immemorial had they been taken out of Russia by local and foreign merchants.

Not all people know, perhaps, that malachite is a mineral of copper, a metal with which the entire history of civilization is inseparably connected.

You must certainly remember the dreadful picture of destruction described by Academician Fersman to illustrate the meaning of iron to life. But what if copper and not iron should vanish from earth tomorrow? How will we be without this very familiar and very important metal?

In the volume of world production and consumption copper firmly holds third place, with only iron and aluminium ahead of it. But still our contemporary could perhaps survive the loss of copper: the 20th century has provided mankind with a whole lot of metals characterized by incredible and widely differing properties. As for our ancestor cave-dwellers, such a loss would be extremely unfortunate: for them copper was practically the only available metal from which they could make their simple weapons, implements of labour and other articles. True, they also had stone as a material for all those things, but it was clear even then that it was vastly inferior to metal, and the stone tools they had inherited from their Sinanthropus and Neanderthal forebears seemed quite obsolete even in those days.

Along with gold, silver, iron, tin, lead and mercury copper makes up the "magnificent seven" of the metals, those that people have intimately known from the



earliest times. It is suggested, for example, that the acquaintance with copper is ten millennia old. And of this period only about two or three millennia (in terms of history, quite a short while) can be described as a "nodding" acquaintance. Subsequently copper had become part and parcel of life of the primitive man, having replaced stone and the Stone Age and ushering in the Bronze Age.

But why was it that copper and not some other metal was the first that man should have held in his hands? Why was it destined to play such a crucial role in the development of human society?

Of the seven prehistoric metals it is only gold, silver and copper that occur as native metal, that is, in the form of nuggets some of which are very big (the biggest of copper nuggets ever found weighed 420 tons). As to gold and silver, our forebears came across them so seldom that those metals could not find any extensive use. But copper is fairly widely distributed in nature and besides, it is easily malleable

and fairly easily worked. That was why man made himself a copper tool. Although it was not as hard as the stone one, its life turned out to be much longer since the edge that became blunt could be whetted and used over and over again.

The third millennium B.C. saw the birth of one of the Seven Wonders of the World—the erection of the Great Pyramid of Khufu (in Greek Cheops) in Egypt. This grand edifice, the Pharaoh's tomb, was made from 2300000 stone blocks, weighing 2.5 tons each and each cut and finished by copper tools.

Gradually people learned how to extract copper from ores. Particularly well-known were the copper mines on the island of Cyprus, to which, it is suggested, copper owes its name ("cuprum" in Latin). According to some researchers, the Russian word "med" comes from the word "smida", the name which ancient tribes living in the European part of Russia used for metal in general.

The next step in the history of copper was the excellent alloy of copper with zinc—bronze. The Bronze Age which came after the "Copper Age" marked a whole epoch in the development of world culture. But it

was for a long time that bronze had been used only for the making of objects of luxury and ornaments. If ancient Egyptians had some sort of an ad business, then they must have had papyrus signs in crowded places put up by jewellers advertising bronze mirrors as the best gift for a woman.

The word bronze comes from Brindisi, the name of a small town and port on the Adriatic coast of Italy, which had always been famous for its bronze items. The Latin "Es Brundisium" (from Brindisi) subsequently became "bronze".

Perhaps it would be correct to say that the Egyptian priests were the first alchemists in the history of science. Some manuscripts found when an ancient tomb was opened in Thebes related the secrets of making gold from copper. It seems that it was enough to add zinc to copper for it to become gold (the alloy of these elements, brass, really resembles gold). Alas, this gold had a flaw: after a while it broke out in "sores" and "rash" of a greenish colour (unlike gold, brass becomes oxidized). In order to cure that "disease", the priests asserted, it was necessary to pray earnestly and know reliable incantations.

Copper and bronze were known not only to Egyptians but also to Indians, Assyrians, Romans and Greeks. In his *Iliad* Homer describes Hephaestus, the God of fire and metal, forging a copper shield for the hero of the Trojan war Achilles: "Himself he did plunge the impregnable copper into the flames of that glowing fire ..."

It was back in the remote past that copper and bronze had won the hearts of sculptors and engravers. They learned how to cast bronze statues, and some of them of a gigantic size, as early as the 5th century B.C. At the beginning of the 3rd century B.C. the Colossus of Rhodes was erected in the ancient port of Rhodes on a small island in the Aegean Sea. It was a bronze statue of Apollo (later identified



with the sun-god Helios), about 100 feet high (32 metres) which was considered, along with the Great Pyramid of Khufu, one of the Seven Wonders of the World. It is claimed that it towered over the Rhodes inner harbour and was so tall that even the biggest vessels easily sailed beneath it. Unfortunately this magnificent creation stood for only a little more than 50 years: it was destroyed in an earthquake and sold to Syrians as scrap metal. At present rumours are circulated that the Rhodes authorities plan to restore the statue in order to attract more tourists. But the resurrected Colossus will be made from aluminium and there will be a night bar in its head.

The Japanese were outstanding masters of bronze casting. The magnificent sculpture of Buddha in Todaidzi Temple cast in the 18th century weighs more than 400 tons. A creation like that really required great skill.

Surviving to this day are the unique bronze figures cast many centuries ago—Marcus Aurelius, Discus Thrower, Sleeping Satyr and others. These facts illustrate the important role of bronze in antique art.

In later epochs this alloy continued to be a favourite with sculptors. Recall the immortal "Bronze Horseman" the monument to Peter I cast in St. Petersburg by the French sculptor Falconet.

But it is not only copper as such or its alloys that were so well-known in antiquity, but also some of its chemical compounds. Sir Humphry Davy, the British chemist, analyzed some old frescos and discovered that the bright green paint in them was copper acetate. In old Russia this paint was called "yar-medyanika" (verdigris), and the recipe of its preparation was quite simple: "Take goat-milk cheese and honey and put it in a copper vessel, put copper into it and cover it with copper. Seal the cover with dough and leave it on the stove for two weeks."

Simple, isn't it? Verdigris was also found in the paints discovered on the walls of the therms belonging to the Roman Emperor Titus and in the frescos of Pompeii.

Among the items of merchandise sold by Alexandrian traders in great demand was the so-called "copper green": in those bygone days women liked to paint green circles under their eyes with it. But history repeats and this colour has now again become part of women's make-up.

On the territory of what today is the Soviet Union copper mines appeared something like two millennia before our time. In the excavation sites of Transcaucasia, Siberia and Altai the finds included copper knives, arrow-heads, bronze shields, helmets and other articles dating to the 8th-6th centuries B.C. But the first attempts to organize industrial copper smelting were made only at the beginning of the 8th century when copper ore was discovered on the river Tsilma in the north of the European part of Russia (in the region of today's Archangel).

At the beginning of the 16th century such "defense industry enterprises" as the Cannon House and Cannon Yard in Moscow were already casting bronze cannon of many calibers. Russian cannon-founders were great specialists. Even today the 40-ton Tsar Cannon cast from bronze by Andrei Chokhov in 1586 is considered a masterpiece. Another masterpiece, the bronze Tsar Bell by the father and son Matorin and weighing more than 200 tons was cast in 1735 for Ivan the Great's belfry. The cupola of this outstanding monument of 18th century architecture is covered with gilded copper sheets. Copper sheets also face the southern door of the Cathedral of the Dormition, the main temple of old Russia in the Moscow Kremlin. When St. Basil's Cathedral was being reconstructed it was decided to replace the iron cupolas with copper replicas, since the Moscow microclimate had noticeably changed since the time the



Cathedral was built and the iron cupolas were beginning to rust.

Russia was constantly in need of copper and prospecting for it was continuous. In the middle of the 17th century the merchant Semen Gavrilov was sent to the Olonets uyezd "to seek copper ore". He was lucky and really found it. One surviving document (dated 1673) states that the Olonets voyevode (governor) was told to clear the road from the mine to the works one and a half versts (0.99 mile) away. Somewhat earlier, in 1652 the Kazan voyevode reported to the tsar that "a lot of copper ore has been found" and that "we are putting up factories to work it".

But still copper was in short supply. The shortage was felt particularly acutely during the war with Sweden of 1700-1721 (it is incredible that throughout the whole war period Russia was buying copper and iron in Sweden).

In the battle of Narva the Swedes defeated the Russian army and Peter I, realizing the need for a powerful artillery, decided to increase copper-smelting and confiscate all bronze bells and other bronze articles from the Church. Suppressing its resistance, Peter used all bronze for building cannon.

The battle of Poltava confirmed Peter's wisdom: the Swedish troops equipped with only four guns were defeated by the 72 Russian bronze guns. Sweden's defeat was of decisive importance for the development of the Russian national economy.

After the victory at Poltava Peter carried out another momentous reform: minting of copper coins. The rapidly developing domestic trade required cheap money material to replace silver which was essential as a foreign currency. And once more the bronze bells had to be sacrificed.

In 1763 a new mint was commissioned at Kolyvan in Altai. It made one-, five- and ten-kopeck copper coins. Along the edge of the new coins ran the inscription "Siberian Coin". Almost four million

roubles worth of coins had been made by 1781.

In subsequent years copper-smelting continued developing. Dozens of smelters emerged in the Urals and Altai. By the end of the 19th century copper production had already begun also in the Caucasus and Kazakhstan.

At about the same period copper metallurgy began to develop in the Far North (former Yenisei guberniya). In 1919 the well-known geologist Nikolai Urvantsev discovered the remnants of a copper furnace in Dudinka. It was established that the furnace was built in 1872 and that remarkable events preceded its construction.

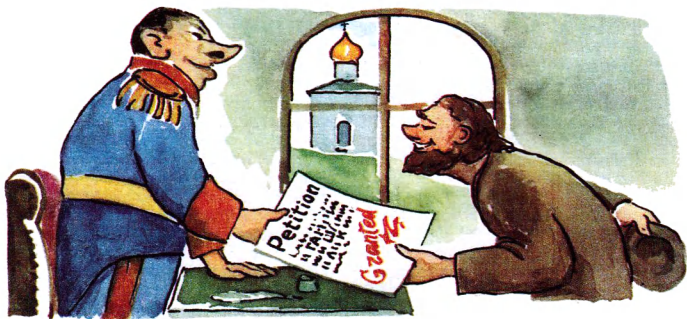
The fact that there were copper ores in Taimyr had been known for a long time, but copper-smelting could not develop there because of the high cost of building materials, especially bricks. Finally in 1863 Kipriyan Sotnikov, a merchant, devised a shrewd plan. He requested the governor's permission to build a wooden church in the village of Dudinka on his own money. The governor naturally could not refuse such a fine "god's servant" and the merchant was given the permit. But

Sotnikov's clever plan was based on the fact that the people in the governor's office were unaware that Dudinka already had one church, a brick one. Having built a wooden church quickly, the enterprising merchant pulled down the brick church and used the "holy" bricks for the building of a shaft furnace, the forefather of the Norilsk Mining Complex, the contemporary giant of nonferrous metallurgy launched not long before the Second World War.

At the beginning of the 20th century almost three-quarters of Russia's copper-smelting industry was in the hands of foreign capitalists. In 1913 only 17000 tons of refined copper was turned out. That was nothing close to what the country really needed.

During the Civil War and the Entente's intervention in Russia (1918-20) copper-smelting had actually stopped. Many copper mines were destroyed or flooded and the smelters stood still—there was neither the work force, nor materials or fuel.

It was during that difficult period that the Soviet Government was approached by the British industrialist Lesley Urkwart,



a former concessionaire, who offered, on fettering terms, to restore the Karabash copper mine which was considered one of the richest in the country. Lenin categorically refused him. But Urkwart's desire to make himself a tidy sum out of Russian copper was great and, knowing how rich our land was in minerals, he made another "business" offer to the Soviet Government: "Would you let me poke a bit here and there in the Kirghiz steppes near Balkhash and beyond it? You won't get around working in these parts for another 50 or 100 years anyway."

But the leaders of Soviet industry realized that to "poke a bit" would amount to directly undermining the young Soviet national economy. Urkwart had to give up his enticing plans. The Soviet people got down to restoring the national industry by themselves.

In order to implement Lenin's plan for the electrification of Russia (GOELRO) the country needed copper, a lot of it. On May 5, 1922, the restored Kalata copper smelting works turned out its first batch of copper. That date can rightly be considered the birthday of the Soviet nonferrous metallurgy.

Soon came the turn of Balkhash. Already in the autumn of 1928 (not in 50 or 100 years) a geological party was delegated there. At the foothills of Mount Bentau Ata, right in the place Mr. Urkwart had such a great desire to "poke a bit" the geologists found copper. A while later Valerian Kuibyshev, Chairman of the Supreme Economic Council, reported to the 16th Communist Party Congress: "New deposits of copper ore have been discovered, in particular the Kounradsky deposit."

In 1932 the construction of the Balkhash Mining Complex was started there under exceedingly difficult conditions. Often caravans of camels were the only transport taking freight to a distance of 400 kilometres. It was sheer enthusiasm that

helped people to endure all hardships. The Balkhash Complex was commissioned in 1938.

Other copper-smelting enterprises went up during the first five-year periods and after the war. Today the copper-smelting industry is a leading branch of the Soviet nonferrous metallurgy.

In what fields of contemporary technology is copper, one of the oldest metals known to man, used?

The most important properties of copper are its high electrical and thermal conductivity. There is only one metal—silver—that is characterized by higher conductivity of heat and electricity. But silver is expensive and cannot be used on a sufficiently large scale in technology. In its electrical conductivity copper exceeds iron 5 times, aluminium 1.5 times, zinc 3 times and titanium 35 times. This is why it is considered to be the main metal of electrical engineering.

It is copper we see in transformers and in automobile engines, in TV and radio sets, in most sophisticated electronic devices and in metalworking machine tools. It is copper that is used in chemical facilities and in tools employed for work with explosion-hazard or inflammable substances where the "sparkling" steel cannot be used.

The number of copper alloys applied in diverse industries is constantly growing. While some 30-40 years ago only the alloys with tin were regarded as bronze, today we have aluminium, lead, silicon, manganese, beryllium, cadmium, chromium and zirconium bronzes.

Copper coins, for instance, are made from aluminium bronze (copper with about 5 per cent of aluminium). Copper coins were first introduced in Russia in the 17th century. That event resulted in an uprising in Moscow (1662) which went down in Russian history as the "copper riot". The direct cause for the uprising was the replacement of silver money with

copper coins which resulted in a rise of prices for bread and other foodstuffs. The people were exhausted by the lengthy war with Poland and Sweden and by frequent crop failures and heavy taxes. But the tsar savagely put down the "copper riot": several hundred people were killed, hanged or drowned, several thousand were imprisoned and more than a thousand were exiled to Siberia and Astrakhan.

The first Soviet coins were minted soon after the 1917 Revolution. In 1920 in Khorezm (Central Asia), two years before the mint was reopened in Leningrad coinage was begun of 20-, 25-, 100- and 500-rouble pieces under the decree of the Council of Commissars of the Khorezm People's Soviet Republic. Those coins with inscriptions in, the Russian and Uzbek languages were taken out of circulation only after the Soviet state banknotes were issued.

Paradoxical as it may seem, copper coins can sometimes be worth more than gold ones. A few years ago an unusual auction was held in London. Only one item was on sale: one copper penny. But those present knew that it was worth far more than a penny.

In 1933 the London Mint coined only six such coins. Five of them are kept in the British Treasury and the British Museum and the sixth was in a private collection. Its new owner had to pay 2 600 pounds for it—more than 600 000 times the nominal price.

Brasses (copper with zinc) constitute a large group of copper-base alloys. Additions of other elements give them most diverse properties.

Lately copper and its alloys have begun to be replaced by other metals, above all aluminium, in some branches of technology. In the United States for example, aluminium has fully replaced copper in high-voltage transmission lines. Furthermore, it can well be supposed that plastic goods will successfully be

competing with copper within the next few years.

The tendency to replace copper is largely to be explained by a relative scarcity of this metal. This is why the greatest significance is attached to exploring and developing new deposits of copper ore. Quite recently a unique deposit was discovered at Udokan (USSR). It is estimated that the Udokan copper reserves are twice as large as those of another big deposit, the one at Jezkazgan in Kazakhstan. Reserves of complex ores which also include copper have been found in the region of Talnakh beyond the Polar Circle.

Not long ago copper played a trick on the Norwegian ship, the *Anatina*, which was taking a consignment of copper concentrate to Japan. It turned out that the copper in the hold created a good electrolytic couple with the steel of the ship's hull while the vapours of seawater played the role of the electrolytic bath. Electrolytic current developed, corroding the sheathing of the ship to such an extent that she sprung several leaks.

Another remarkable aspect of copper is that it is a bioelement, that is, an element essential for the normal development of flora and fauna as a catalyst of the chemical processes taking place in the cells.

Absence or lack of copper in plant tissues reduces their chlorophyll content, causing the leaves to yellow and making it impossible for the plant to bear fruit, as the result of which it may die.

In the animal kingdom the octopus, cuttlefish, oyster and some other molluscs are characterized by the highest content of copper in the blood. In cancrroids and cephalopods copper is present in the blood's respiratory pigment, hemocyanin (up to 0.33-0.38 per cent), playing the same role as iron in the blood of other animals. Combining with atmospheric oxygen, hemocyanin turns blue (hence the snail's

"blue blood"), and when it gives up its oxygen to the tissues, the blood becomes colourless. In higher animals and in humans copper is mainly concentrated in the liver. The human organism's daily requirement in copper is about 0.005 gram. If the copper supply taken with food is inadequate, anemia develops and weakness sets in.

This is perhaps why many people ascribe medicinal properties to copper. Nepalese consider copper to be a sacred metal which promotes the power of mental concentration, improves digestion and cures intestinal disorders (patients are given water from a glass containing a few copper coins). One of the largest and most beautiful temples in Nepal is called Copper Temple.

Polish scientists have found that carps living in waters where copper is present are bigger in size. Meanwhile in pools and lakes where there is no copper a fungus which is harmful to the fish grows quickly.

But unlike the copper-loving carp, some more impressive inhabitants of the blue kingdom, such as sharks, cannot bear the presence of this element, or to be more exact, its sulphuric compound, copper sulphate. Large-scale experiments to study this "anti-shark" substance were conducted in the United States at the beginning of the Second World War when quite a number of ships were sunk by torpedoes and surviving seamen needed protection from the sharks. Many scientists and shark hunters took part, including Ernest Hemingway who indicated areas where he himself had hunted those animals. The success of the experiment exceeded all expectations: the sharks greedily seized upon all baits without the copper sulphate and expertly avoided the control ones that had it.

The effect of the "anti-shark" drug was at first doubted by Australian specialists. "For our sharks," they said (and Australian sharks are considered the most vicious), "this is like a headache pill, or

like spice in the stew." However when the "drug" was tested in the notorious Shark Bay off the western coast of Australia, it was effective in 95 per cent of the cases.

One of the methods of copper extraction is also based on biological processes. At the beginning of the century copper mines were closed down and flooded in Utah (the United States), since the owners had decided that the ore had been exhausted. When the water was pumped off two years later it was discovered that it had 12 000 tons of copper in it. A similar case was registered in Mexico where 10 000 tons of copper were "ladled out" of discarded mines within just one year.

Where did the copper come from? Scientists found that among numerous bacteria there are some that thrive on the sulphuric compounds of some metals. Since in nature copper is usually combined with sulphur, these bacteria "like" copper ores. By oxidizing copper sulphides insoluble in water, the microbes turn them into readily soluble compounds and the process is very fast. To illustrate. While in the process of ordinary chemical oxidation of chalcopyrite only 5 per cent of copper is leached out in 24 days, 80 per cent of the element is extracted in experiments with bacteria in just 4 days. The superiority of the microbiological "miners" is thus obvious. True, it must be admitted that practically ideal work conditions were created for them: the temperature was between 30 and 35°C, the mineral had been crushed and was being continually stirred up. But still it has been established experimentally that the bacteria are really quite undemanding: they pursued their "hobby" even under the rigorous conditions of the North (on the Kola Peninsula).

The role of the bacteria is particularly important at the closing stages of exploitation of a mine, when as a rule the depleted rock still contains from 5 to 20 per cent of ore. The extraction of those

"scraps" is not economically efficient, and often simply impossible. But for the bacteria it is quite easy to get to the copper graveyard and collect all the crumbs left there.

The microorganisms can also be used for the processing of dumps. This is what happened at the Cananea mine in Mexico where about 40 million tons of dumps had accumulated. Although the copper content in them was infinitesimal (0.2 per cent) water from the mine was poured over them and let ooze into underground reservoirs. Three grams of copper were extracted from every litre of it. In one month 650 tons of metal was produced from "nothing".

Bacteria have also been "employed" at some mines in the Soviet Union. The first experimental installation for bacterial leaching out of copper was commissioned back in 1964 at the Degtyarsky mine, one of the biggest in the Urals, where a "deposit" of impoverished copper ore had grown over many years in the vicinity of some exhausted mines and in the slag heaps of an ore-dressing factory. That ore was given away to the microbes whose "efforts" resulted in the production of many tons of the much-needed metal. At present an industrial facility has been set up at Degtyarsk. Bacteria are being "mass-recruited" at other enterprises in the Urals and Kazakhstan as well.

A study carried out at the Institute of Microbiology under the USSR Academy of Sciences has revealed that the "tastes" of industrial microbes are diverse. Along with copper they can also be used for the extraction of iron, zinc, nickel, cobalt, titanium, aluminium and other elements including the precious uranium, gold, germanium and rhenium. Several years ago researchers at the Institute demonstrated that rare metals, such as gallium, indium and thallium were also possible to produce by means of bacterial leaching out.

Biometallurgical processes have



extremely good prospects. It is obvious even now that underground leaching is the cheapest method of copper production: no miners will be needed in the pits, neither will there be a need in roasting and ore-dressing factories. All this difficult work is readily done by thousands of millions of tiny "metallurgists", who like fairyland gnomes work day and night to help people.

This is what Academician Alexander Imshenetsky, the well-known Soviet microbiologist, wrote a few years ago: "Microorganisms play a great role in the natural cycle. The ideas of geomicrobiology set forth by V. I. Vernadsky find practical application already now. It is known that the microbes are responsible for the formation of a number of mineral ores. Even Peter I in his time ordered the famous 'coin' ore to be extracted from the bottom of the lakes in the north of the country to make cannon. That ore was the creation of microbes... The wide application of microbes in mining as active 'producers' of va-

uable metals is a matter of an immediate future. Some twenty years ago this seemed fantastic, but today people have learned to guide and intensify the activities of these invisible 'metallurgists'. At present in a number of places in the world they produce uranium, copper, germanium and other metals in commercial amounts by pumping water rich in microorganisms into discarded (because of depletion) mines. It is doubtless that the use of microbes in hydrometallurgy will make it a leading industry at the end of this century. Microcultures that oxidize compounds of sulphur and other elements will be one of the best and cheapest metallurgical 'agents' and moreover, their production can easily be fully automated".

The alliance of geology and botany, the so-called indicational geobotany, is growing stronger and stronger. In his *Ural Tales* Bazhov described magic flowers and the stone-breaking grass (lady's cushion) of the

mountains that showed people where underground treasure-houses of gold, iron and copper were concealed. The roots of many plants reaching deep into the ground pump solutions of different substances from it. If a plant grows in the vicinity of some metal, its roots, branches and leaves will definitely contain more of this metal than normally. And it must be said that each plant has its "favourite dish": maize and honeysuckle are "well disposed" to gold, violets "prefer" zinc, wormwood "likes" manganese and pine has a "soft spot" for beryllium. An increased content of some element in a plant is a signal to begin a geological survey of the region. Such surveys often end in the discovery of new deposits, as happened in Kazakhstan and Tuva where plants helped to find copper.

To make a long story short, it must be said that although the "Copper Age" has long been past history, mankind cannot part with copper, its reliable ally.

A "CLOTHING" FOR URANIUM RODS



Martin Klaproth makes a discovery.—What did you dream?—An old belief.—Looking for work.—Losses in acid.—Many-sided activity.—No fear of overheating.—In search of a calling.—The brother's fate.—"Private".—The Nautilus' reactor.—Merits and demerits.—Problem after problem.—Riches in refuse dumps.—On the ocean shore.—"Sidelines".—Nernst's lamp.—What's going on in Montlouis?—The sun city.—A misunderstanding.

In 1789 while analyzing a variety of the mineral zircon Martin Heinrich Klaproth, the German chemist and member of the Berlin Academy of Sciences, discovered a new element which he called zirconium. Owing to its beautiful colours ranging between golden, orange and pink—this mineral was considered a precious stone as early as the epoch of Alexander the Great. Its name evidently derives from the Arab "zarqun" meaning "golden". Other names of this mineral also occur in the literature: hyacinth, jacinth, jargoon and jargon.

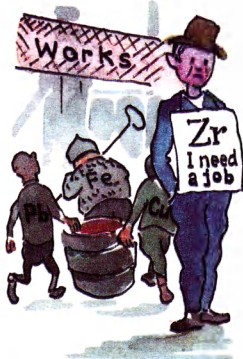
In old times zircon was used not only as an ornament but also as an amulet which "makes the heart rejoice, chases away woe and improper thoughts, sharpens one's wit and builds up one's honour". An ancient "doctor" wrote in his book on medicine, "he who carries with him a red *yakhont*¹ will not dream horrible and violent dreams, will be firm in his heart and honest with people".

For the first time zirconium was extracted in its free state by the Swedish

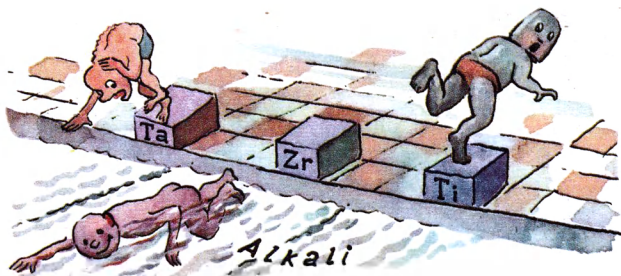
chemist Jons Berzelius in 1824. But to obtain pure zirconium was an impossibility then and its physical properties had remained unstudied for a long time. For decades had zirconium, like many other most valuable metals, been unable to find itself a job it would "enjoy", while metals like iron, copper and lead which "knew" how to "show themselves" in a favourable light had plenty to do.

It was only at the beginning of this century that scientists were able to extract zirconium free from impurities, and carefully to study the properties of this metal. They found that it was always accompanied by hafnium. For more than 130 years had chemists overlooked the fact that hafnium was contained (and sometimes in substantial amounts) in zirconium. This is to be explained by the similarity in the chemical properties of the two metals, although they also have "serious differences". But more about it later.

Pure zirconium outwardly resembles steel, but is stronger and very ductile. One of its most remarkable properties is its resistance to many aggressive media. In anti-corrosion properties it is even superior to such resistant metals as niobium and titanium. While stainless steel immersed in five-per-cent hydrochloric acid loses something like 2.6 millimetres a year at a temperature of 60°C and titanium, about one millimetre, zirconium's loss is only one-thousandth of that. Zirconium's resistance to alkalis is even greater. In this respect it is even superior to tantalum which has a well-earned reputation of being an outstanding fighter against corrosion. Thanks to its remarkable corrosion resistance zirconium has found application in neurosurgery—this extremely delicate field of medicine. Zirconium alloys are good for surgical instruments, and sometimes zirconium filaments are used for stitches during brain operations.



¹ In old Russian many gems, including the ceylones hyacinth, were called "yakhont".



After scientists had noticed that introduction of zirconium improved many properties of steel it was acknowledged as a valuable alloying element. In this sphere its uses are varied: it increases the hardness and strength of steel, improves its machinability, hardenability, weldability and fluidity, crushes the sulphides contained in it and makes its structure fine-grained.

The introduction of zirconium in steel increases its scale resistance: after a three hours' holding at a temperature of 820°C the weight loss in grades 40-45 steels containing from 0.16 to 0.37 per cent of zirconium is reduced to a sixth or seventh of that in steel which is not alloyed with zirconium.

Zirconium also considerably increases the corrosion resistance of structural steels. To illustrate. After being kept in water for three months the 20Г steel lost 16.3 grams in weight per sq m, while a specimen of the same steel but with an addition of 0.19 per cent of zirconium lost only 7.6 grams.

Zirconium steel can be heated to very high temperatures without fear of overheating. This makes it possible to intensify such processes as forging, heat treatment and cementation.

The close-packed fine-grained structure and high strength of zirconium steel

combined with good fluidity allow for manufacturing castings with thinner walls than those made from common steel. For example, the 40X steel with an addition of zirconium was used to cast experimental machine parts with 2 mm thick walls. The walls of the same parts cast in the 40X steel without zirconium were at least 5-6 mm thick.

Zirconium also produces good results when alloyed with many nonferrous metals. An addition of zirconium to copper greatly increases its strength, leaving its electrical conductivity almost unaffected. High strength and conductivity characterize the copper-cadmium alloy with 0.35 per cent of zirconium. Zirconium substantially builds up the strength, ductility, corrosion resistance and heat resistance of aluminium alloys. The strength of magnesium-zirconium alloys (0.6-0.7 per cent of zirconium) grows about two-fold. The corrosion resistance of the alloy of titanium with 14 per cent of zirconium in 5-per-cent hydrochloric acid at 100°C is 70 times higher than that of commercial titanium. The introduction of 5 per cent of zirconium to molybdenum substantially increases its hardness. Zirconium is introduced in manganese brass and in aluminium, nickel and lead bronzes.

But however important and honourable

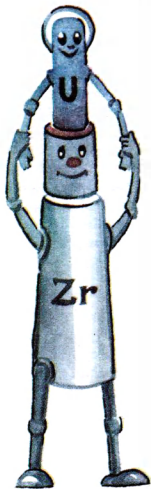
was its role as an alloying element, it was too insignificant for zirconium. Research continued and finally it was given a real opportunity to pursue its true calling. But before discussing this new aspect, let us return to the birthplace of this element, the chemical laboratory of Martin Klaproth.

Zirconium was not the only element that Klaproth discovered in 1789. There was also another one which was destined to play an outstanding role in 20th-century science and technology. That element was uranium. But neither Klaproth nor anyone else could then foresee how the lives of the two brothers—zirconium and uranium—would be shaped. Their paths forked and nothing brought them together for 150 years. The long separation ended only in recent times. At first only a very few of those working in atomic power production, an area with a “No entry” sign

over it, knew about the meeting of the two metals. It took place in the atomic reactors where uranium was used as nuclear fuel and zirconium as a sheathing for uranium fuel rods. But it will be noted for the sake of accuracy that several years before that American scientists used zirconium as material for the nuclear reactor mounted on the *Nautilus*, the first American atomic submarine. But it soon became clear that it was better to use zirconium not for the stationary components of the reactor's active zone, but for the sheathing of the fuel rods. And that was when uranium got into zirconium's “embrace”.

It was for good reason that zirconium was picked: physicists knew that unlike other metals, it easily lets neutrons through (neutron transparency)—exactly the property needed in the sheathing of uranium fuel rods. True some other metals—magnesium, aluminium and tin—are similar to zirconium in this respect, but they are low-melting and non-refractory. Zirconium, however, melts at a temperature of 1850°C and can stand the temperatures of the atomic power industry perfectly well.

Zirconium also has some flaws which could have prevented it from doing its responsible work in the atomic reactor. The point is that only zirconium of the highest purity is transparent to neutrons. This is where we must remember hafnium once more. In its chemical properties hafnium can be considered a twin of zirconium. But its attitude to neutrons is diametrically opposed to the attitude of zirconium: hafnium greedily absorbs them (500-600 times more so than zirconium). Furthermore, the presence of hafnium in zirconium even in “homeopathic” doses can spoil its “blood” and destroy its neutron transparency. The standard of the so-called “reactor pure zirconium” allows the presence of not more than 0.002 per cent of hafnium. But even this “droplet” reduces the transparency six and a half times.



Since zirconium and hafnium naturally occur together, it is an exceedingly difficult task completely to separate one from the other. But still chemists and metallurgists were compelled to find a way of doing it, since the atomic industry was in great need of a structural material.

When that problem was solved, another one arose: during casting, structures from the purest zirconium had to be protected from "alien atoms" which would subsequently become an insurmountable obstacle on the way of the neutrons, bringing to naught all the good properties of the metal. Apart from that, welding had to be carried out in a way that would preserve the metal's homogeneity, in other words, the weld should be characterized by the same properties as the metal being welded. The answer was found in the electron beam. The purity and precision of the electron-beam welding made zirconium the material for the sheathing of uranium fuel rods.

That was when a dramatic leap was registered in the production of zirconium: during the 1949-1959 decade the world output of this metal went up 1 000 times! Use was made of the large amounts of zircon sand which had earlier been ignored along with the wastes produced during extraction of other minerals. For example in California, substantial amounts of zircon were dragged out from ancient river-beds—there was no one who would want it. On the Pacific coast of Oregon (USA) chromite was mined during the war and with it, some zircon. Industry had no use for this metal then and it was left where it had been mined. When the zirconium "boom" began soon after the war, all those dumps became buried treasure.

At present big deposits are being developed in the United States, Australia, Brazil, India and West Africa. Often coastal sands prove to be excellent zirconium ore. In Australia zirconium



placers stretch for nearly 150 kilometres along the ocean coast. The Soviet Union also possesses considerable zirconium reserves.

The demand for zirconium has been growing yearly, this being a metal for which new "jobs" are created all the time. Its ability avidly to absorb gases is made use of in the making of incandescent lamps and electron tubes. A mixture of metallic zirconium powder and combustible materials is used for the manufacture of flares of exceptional brightness. Zirconium foil produces 50 per cent more light when it burns than aluminium foil, while consuming the same amount of oxygen. Zirconium flashes are very convenient, since they take little room and can be as small as a thimble. Rocket designers have been taking an increasingly closer look at zirconium alloys. It is very likely that the refractory alloys of this element will be used in spaceships which will be engaged on regular space journeys.

Raincoats owe their moistureproofness to the salts of zirconium which enter into the composition of a special impregnating emulsion. Zirconium salts are also used for the production of coloured printing inks, special varnishes and plastics. Zirconium compounds act as catalysts in the process of producing high-octane engine fuel. Zirconium sulfates are distinguished for their excellent tanning properties.

Zirconium tetrachloride has also found an interesting application. The electrical conductivity of this compound changes with pressure. The work of the electrical pressure transducer is based on this property: the slightest change in pressure changes current in the instrument's circuit, causing the pointer to deflect. The gauge is extremely sensitive and is graduated to read pressures within the range of one-hundred-thousandth of an atmosphere to thousands of atmospheres.

Piezocrystals are used in many radio instruments—ultrasonic generators, frequency standards and others. In some cases they have to operate at high temperatures. Of special interest, therefore, are the crystals of lead zirconate whose piezoelectric properties remain practically unchanged at temperatures up to 300°C.

While we are on the subject of zirconium we must not overlook its dioxide, which is one of the most refractory substances in nature, its melting point being somewhere around 2700°C. It is used for the making of high-heat products, including heat-resistant enamels and glasses. But zirconium boride has even a higher melting point and is used for thermocouple protection tubes enabling them to remain submerged in molten iron for 10-15 hours and in steel for 2 or 3 hours (quartz tubes can withstand only one or two 20-25 seconds' dippings).

When heated zirconium dioxide has the remarkable ability to emit light so intensively that it can be used in illumination engineering. This property

was first noticed at the end of the last century by Walter Nernst, the well-known German physicist. He devised a lamp (known as the Nernst lamp) in which the glow bars were made from zirconium dioxide. This substance is still used for lighting in some laboratory experiments.

In France scientists have developed a method of obtaining zirconium from its dioxide by means of solar energy. A group of researchers under Professor Felix Trombe have designed a sun furnace and put it up in Montlouis, a 17th-century fortress in the Eastern Pyrenees 1500 metres above sea level. Its work was demonstrated at a symposium on the utilization of solar energy in Montlouis.

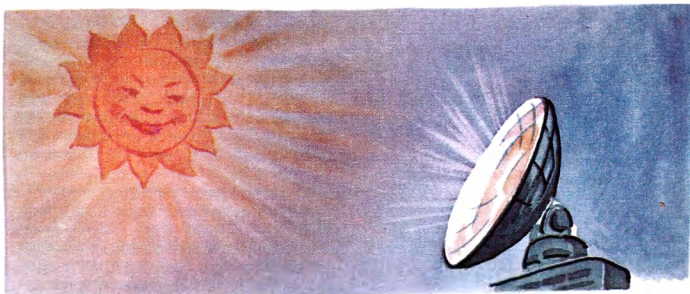
This is how the process of obtaining "sun" zirconium was described by one of the participants in the symposium:

"Slowly, almost imperceptibly, a special platform raises a handful of white powder to the focus of a large parabolic mirror. Now the platform has reached the focus and a blinding white flame flares up before the eyes of the scientists and engineers.

"The white powder is zirconium dioxide. Placed in the focus of the parabolic mirror where the temperature of the concentrated sun-rays reaches 3000°C the powder melts. The flash can be watched only through dark glass. The small pile of the molten substance on the platform resembles a volcano eruption dating to a remote geological era."

The installation has a special reflector consisting of numerous mirrors and measuring 12 metres in diameter. It is equipped with photoelements which enable it automatically to turn on its axis following the sun. The reflected rays are directed to a parabolic mirror, 10 metres in diameter. The heating capacity of the mirror which focuses the sun-rays into the mouth of the furnace is equivalent to 75 kilowatts.

Ten kilometres from Montlouis, in a small village of Odeillo the world's



biggest sun furnace is in operation. The eyes of those coming to the "sun capital" as the local people proudly call their village, meet an unusual scenery that can be described as a set of a science fiction film during shooting on location. Near an old church with a tall slender spire there stands a super-modern multi-storeyed building housing the Solar Energy Laboratory. The whole northern façade of it is a great parabolic mirror, 50 metres in diameter. On a mountain slope opposite the building there are dozens of mirrors of impressive size (heliostats) arranged in rows. The heliostats reflect the sun-rays upon the parabolic mirror from where, focussed into a beam, they get into the furnace, heating it up to a temperature of 3500°C .

The Odeillo-Font-Romeu furnace is capable of producing almost 2.5 tons of zirconium a day (the daily output of the furnace in Montlouis is only 60 kilograms). The heat developed by the reflected sun-rays is equivalent to 1000 kilowatts of electric power.

The main advantage of the sun furnace is that during smelting no impurities get into the metal—there is nowhere for them to come from. Owing to this fact, the metals and alloys produced by such a furnace are in high and continuous demand. And another advantage is that the energy of the generous Sun is free.

In conclusion one misunderstanding has to be cleared up. The earth's crust contains more zirconium than say, copper, nickel, lead or zinc. But still zirconium is referred to rare metals. In the past this was to be explained by the fact that zirconium ores were widely scattered, that it was difficult to produce this metal and also by the fact that in technology zirconium was really a "rare guest". But nowadays when zirconium production is rapidly growing and it finds more and more useful applications, the term "rare" is becoming unjustified. But there is no forgetting the past and if zirconium is asked about its origin it can proudly say "of the rare".

THE FORTY FIRST



Where do you live?—In order to avoid disagreement.—The neighbours are intrigued.—A parcel from the banks of the river Columbia.—150 years after.—Two discoveries.—Another questioning to be instituted.—In honour of the goddess of grief.—“Columbians” are reconciled to their fate.—As thick as thieves.—The game is worth the candle.—It is an ill wind that blows nobody good.—Recognition comes.—Important things to do.—Vacuum helps.—Nothing to be feared from frost.—Jhe Westing—house’s mistake—Resistance disappears.—Zirconium’s competitor.—Enemy of gases.—“Important medical worker”.—Monetary operations.—Prediction comes true.

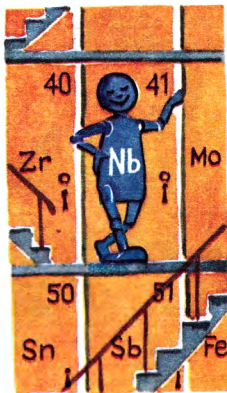
By the middle of the past century several dozen chemical elements had been discovered. But they had no "shelter over their heads", no place to go. It was only in 1869 that Dmitry Ivanovich Mendeleev built the magnificent edifice of his Periodic Table and all the elements which had been discovered by then were finally given an abode.

When "apartments" were being distributed no consideration was given to such things as the future tenant's services to science and engineering or to the length of the service record. Only personal characteristics were taken into account, the atomic weight, first and foremost, as well as the resident's inclinations and resemblance to the closest neighbours. To rule out any possible disagreements between tenants with different character and different outlooks, they were given apartments as far away from one another as possible.

A new tenant with a beautiful name, Niobium, took up residence in Apartment No. 41, fifth entrance (fifth period, sixth row). The neighbours were intrigued: Who is he? Where does he hail from?

...In the middle of the 17th century, in the basin of the river Columbia, North America, a heavy black mineral with golden veins of mica was found and, along with other specimens collected in different parts of the New World, was sent to the British Museum. For 150 years the mineral (subsequently called "columbite") had been kept there in a glass case as a specimen of iron ore. In 1801 Charles Hatchett, already then a well-known chemist, became interested in the beautiful mineral. He analyzed it and found that it indeed contained iron and also manganese and oxygen. But that was not all: there was an unknown element as well. When tested, it formed a substance with properties of an acid oxide. The chemist gave it the name columbium.

A year later (1802) the Swedish scientist Ekeberg found another new element in some Scandinavian minerals. He called it



Tantalum in honour of the mythological Tantalus. Apparently this name was to symbolize the difficulties ("torments of Tantalus") which chemists had come up against when they tried to dissolve the oxide of the new element in acids. The properties of tantalum and columbium turned out to be absolutely identical and many chemists, including Berzelius, drew the conclusion that they were dealing not with two different elements but with one, namely, tantalum.

Later Berzelius began to doubt this conclusion. He wrote to his pupil, the German chemist Friedrich Wohler: "I'm sending you back your X which I questioned as cleverly as I could, but was given vague answers. 'Are you titanium?' I asked. It answered, 'But Wohler told you that I was not titanium!' I also established it for a fact. 'Are you zirconium?' 'No', it answered. 'I dissolve in soda and zircon earth doesn't.' 'Are you tin?' 'I contain tin, but very little of it.' 'Are you tantalum?' 'I'm related to it, but I gradually dissolve in caustic potash and when I settle from it,



I'm coloured yellow-brown.' Then what the hell are you?' I asked and then it seemed to me that it answered, 'They didn't give me a name.' But I'm not sure if I really heard those words because it was on my right and my right ear is very bad. Since your hearing is better than mine, I'm sending this mischievous creature back to you so that you can put it through another questioning..."

But Wohler, too, failed to grasp the relationship between the elements discovered by Hatchett and Ekeberg. Finally in 1844 the German chemist Heinrich Rose proved that the mineral columbite contained two different elements—tantalum and columbium. Rose gave the latter a new name, "niobium" in honour of Niobe who was, in Greek mythology, the daughter of Tantalus and goddess of grief. But the original name of the element, columbium, was retained for a long time in some countries (e.g. the United States and Britain) and it was only in 1950 that the International Union of Pure and Applied Chemistry (UPAC) Nomenclature Committee decided to put

an end to that "discord" and suggested to all chemists of the world that the element should be called niobium.

At first American and British chemists attempted to have this decision revoked because they thought it unfair, but the UPAC "sentence" was final and not to be appealed against. The "Columbians" had to reconcile themselves to their fate and the new symbol "Nb" appeared in American and British chemical literature.

The joint "residence" of niobium and tantalum in nature, conditioned by their amazing chemical similarity, halted their industrial production for a long time. It was as late as 1866 that the Swiss chemist J. C. Galissard de Marignac succeeded in developing the first industrial process of separating the chemical "twins". It was based on different solubility of some of their compounds: tantalumfluoride does not dissolve in water, while this compound of niobium does so easily. An improved version of de Marignac's process had been in use until quite recently when it was replaced by new and more effective ones, such as selective extraction, ion exchange, haloid rectification, etc.

At the end of the 19th century the French chemist Henry Moissan obtained pure niobium by an electrothermal process: he reduced niobium oxide by carbon in an electric furnace.

In our days the production of metallic niobium is an involved multi-stage process. At first niobium ore is concentrated, then smelted with different fluxes (caustic soda, hydrosulphate or soda) and then bleached out as the result of which insoluble niobium and tantalum hydroxides settle. In order to separate them niobium chloride or oxide is used. By reducing these compounds at a high temperature it is possible to produce niobium in powder form which has to be transformed into a compact malleable metal.

This is how it is done. Under great pressure the powder is first compacted into

rectangular or square bars. The bars are then sintered under vacuum in several stages, the temperature at the final stage reaching 2350°C. After that niobium is charged into a vacuum arc furnace where the process of transforming niobium ore into metal is completed.

Several years ago electron-beam melting was introduced enabling metallurgists to eliminate some extremely labour-consuming intermediate operations, such as pressing and sintering. A powerful electron beam is focussed on niobium powder, causing it to melt; drops of the molten metal fall on the niobium ingot which grows as the powder melts through deeper and deeper, and is gradually removed from the working zone of the furnace.

Now you see what a long way niobium ore travels before it becomes metal. But the game is worth the candle: industry is in great need of niobium today. Paradoxical as it may seem, this metal began its career in refuse dumps: in the past it was considered to be no more than a harmful impurity of tin and when tin was mined, enormous amounts of niobium were dumped. Its fate remained unchanged even when the industrial world had become interested in tantalum: "barren" niobium rock was sent to the dump. But as they say, it is an ill wind that blows nobody good: when niobium was finally given its true worth those dumps became the richest deposits of niobium ores.

After the German chemist W. von Bolton, had obtained in 1907 compact niobium, it was tried, among with many other of its high-melting brothers, as a material for incandescent lamp filaments. It will be recalled, however, that tungsten was the only one that was left to do this work, while all the others had to try their luck in other lines.

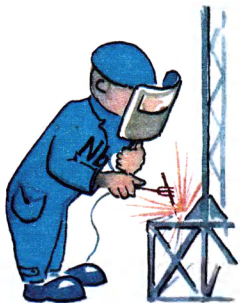
In 1925 the first attempts to use niobium as an alloying element were made. In the United States, for example, it was tested as

a replacement for tungsten in high-speed steel. The tests were unsuccessful, but what was important, was that niobium had aroused metallurgists' interest.

In 1930 the world stock of niobium products (sheet, wire, etc.) was...10 kilograms. But gradually recognition came to this metal and with it, a dramatic rise in production. Niobium was proved to have every right to be regarded as a "vitamin" essential for steel. An addition of niobium to chromium steel improved its ductility and corrosion resistance. It was established that the introduction of niobium to stainless and structural steels (up to 1 per cent) prevented precipitation of chromium carbides along grain boundaries, hence, niobium considerably increases impact resistance under low temperatures. Such steels can easily withstand alternating loads which is of great importance to the aircraft industry.

Niobium was destined to play an important role in welding. This process did not present any special difficulty as long as only common steels were welded. But when welding began to involve special alloy steels of a complex chemical composition, such as stainless steel, it was found that the weld lost many of the valuable properties characterizing the metals being welded. How could the quality of the weld be improved? Attempts were made to change the design of the welding apparatus but in vain. The composition of electrodes was changed, but that did not help, either. Then there were attempts to carry out welding in an inert gas atmosphere—the results were the same. It was at this point that niobium came to the rescue. The steel into which it had been introduced could be welded without fear for the quality of the weld: it was in no way inferior to the base metal.

Until recently great difficulties were experienced when it was necessary to weld two high-melting metals, for example, niobium with molybdenum. Welding under



vacuum was the answer in this case. It was found that under vacuum the melting points of many metals were much lower than under ordinary conditions. Scientists immediately made use of this fact in order to overcome the "rejection mechanism"—vacuum welding of high-melting metals produced excellent results.

Niobium finds a wide application as an alloying element in nonferrous metallurgy. For example, aluminium which easily dissolves in alkalis does not react with them after introduction of only 0.05 per cent of niobium. Copper and its alloys with an addition of niobium gain in hardness, while titanium, molybdenum and zirconium become stronger and heat-resistant. Under low temperatures many alloys and steels turn as brittle as glass. It appears that niobium can deliver them from this drawback. A 0.7-per-cent niobium addition enables the metal to remain strong even at 80°C below zero. This quality is particularly important in components of jet aircraft flying at great altitudes where it is freezing.

Niobium itself readily "forms alliances" with other elements. When the American Westinghouse Company produced a consignment of super-pure niobium, the customers were extremely puzzled on

discovering that it did not melt at temperatures higher than 2500°C, although the melting point of niobium is 2468°C. A laboratory analysis revealed that the "super-pure" niobium contained a little of zirconium. That incident marked the discovery of the super-refractory niobium-zirconium alloy.

The introduction of other metals also gives niobium a number of valuable properties. Tungsten and molybdenum increase heat resistance of metallic niobium, while aluminium makes it stronger; copper improves its electrical conductivity considerably. The conductivity of pure niobium is 8 times lower than that of copper. But an alloy of niobium with 20 per cent of copper is characterized by high conductivity, being at the same time twice as strong and as hard as pure copper. The alliance with tantalum gives niobium an ability to withstand sulphuric and hydrochloric acids even at a temperature of 100°C.

Niobium is indispensable in alloys for the turbine blades of jet engines where the metal must retain its strength at high temperatures. From niobium-containing alloys and pure niobium some components of supersonic jets are made, as well as space rockets and artificial earth satellites.

A few years ago the phenomenon of superconductivity could interest only physicists. At present superconductivity has left the bounds of laboratories and is beginning to "invade" technology where wide opportunities are being offered to it. What does superconductivity mean?

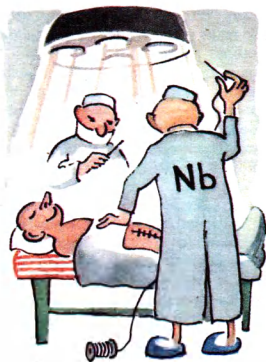
More than fifty years ago it was discovered that at very low temperatures some metals, alloys and chemical compounds begin to conduct current without any loss, that is, resistance disappears in them. But to achieve this effect the metal has to be cooled almost to the absolute zero, that is, to minus 273°C. Of all the known materials, niobium stannide—a compound of niobium and tin—has the highest, hence, the more easily attainable,

temperature under which the state of superconductivity sets in (18K or -255°C). The superconducting magnet coils manufactured from an alloy of these elements produce colossal magnetic fields. A magnet 16 cm in diameter and 11 cm high, in which the coil is a ribbon of this alloy, can generate a field 100 000 oersted strong. It will be noted for the sake of comparison that the strength of the earth's magnetic field is only several oersted.

Pure niobium is likewise widely applied in technology. Its remarkable corrosion resistance has fated it to serve the needs of chemical engineering. It is noteworthy that when niobium is used in the apparatus and pipes involved in hydrochloric acid production it also plays the role of catalyst, allowing for the production of high-concentration acid. Niobium is used as a catalyst in some other processes as well, for example, in the synthesis of alcohol from butadiene.

Niobium is important in nuclear reactors where it is employed alongside zirconium and sometimes even successfully competes with it. Just like zirconium, niobium is characterized by neutron transparency, a very high melting point, considerable refractoriness, colossal chemical resistance and excellent mechanical properties. Furthermore, it shows almost no reaction to molten alkaline metals. Molten sodium and potassium that are used as coolants in nuclear reactors of some types can freely circulate in niobium pipes without causing them any damage. Niobium's ability to retain induced radioactivity is not high and for this reason it can be used in containers for storing radioactive wastes or in installations utilizing such wastes.

Another interesting property of niobium is its remarkable ability to absorb gases. One gram of niobium is capable of absorbing 100 cubic centimetres of hydrogen under an ordinary temperature. And



even under a temperature of 500°C the absorption of hydrogen by niobium is about 75 cubic centimetres per gram. This property is used in the making of high-vacuum electron tubes. When the tubes are evacuated they still retain some quantity of gases which prevents good operation. Niobium deposited on the electron tube components absorbs gas like a sponge, thus ensuring quite a high vacuum. Such components are more economical than those made from tantalum or tungsten and their life is much longer. The life of powerful transmitting tubes with niobium cathodes is as long as 10 000 hours.

Just as tantalum, niobium produces absolutely no effect on tissues in the human organism, but grows together with them and remains inert even after a lengthy action of the organism's liquids. Owing to these properties, niobium has drawn the attention of surgeons and can now consider itself an "important medical worker".

Of late there has been talk that niobium is seriously "contemplating" the idea of taking part in "monetary operations": in view of the short supply of silver American

financiers predict that niobium will be used to make metal money, since this metal costs about as much as silver.

If we analyze data from different sources concerning the content of niobium in the earth's crust, we will see that over the last few decades it has been constantly ... growing. The actual reserves of this metal, naturally, remain practically unchanged, but the number of explored deposits is constantly increasing. During the last few years considerable niobium deposits have been discovered in Africa. Nigeria, where great accumulations of columbite are situated, is the biggest supplier of niobium to the world market.

In our country the Kola Peninsula is rightly considered a treasure-house of minerals. For ages had these parts been

known as barren and useless, although this is what Mikhail Lomonosov predicted as early as 1763: "There are many facts enabling me to conclude that the earth's depths in the North are also rich in Nature's gifts and the shores of the White Sea must have minerals. "During the years of Soviet power numerous important mineral deposits have been discovered there, including the mineral loparite which contains up to 8 per cent of niobium. It is a curious fact that this mineral, discovered in the Khibiny massif by Alexander Fersman, an outstanding explorer of the Kola Peninsula, does not occur in any other place on the globe.

...So much for the tenant in Apartment No.41, the plaque over whose door says "Niobium".

IRON'S ALLY



Impossible to do without spices.— Under an assumed name.— Ancient Greeks made a mistake.— In protest.— A 1600-storey skyscraper.— Accident on a smooth road.— Hairdressers' acquisition.— Holders for the tungsten filament.— Reinforced materials.— The glass changes its colour.— True friends.— The secret of the Samurai swords.— The tank becomes unassailable.— A razor blade.— Kindred souls.— No danger from frost.— Human "spare parts".— The favourite of beans.— What kept "The Redheaded League" together?— Unwelcome guests.— A modest position.— A "war" metal.— High in the mountains.— Millions of metres of wire.— Where are the keys to the coffers?

In order to make a tasty dish the cook adds different spices to it. In order to give steel valuable properties, the steelmaker uses various alloying elements.

Every spice serves a specific purpose. One improves the taste of the dish, another makes it fragrant and appetizing, a third makes it piquant, etc. It is hard to describe everything that spices do. But it is even harder to enumerate all the wonderful qualities that steel acquires when chromium, titanium, nickel, tungsten, molybdenum, vanadium, zirconium and other elements are introduced in it.

This chapter deals with molybdenum, one of the loyal allies of iron.

Molybdenum was discovered by the Swedish chemist, Karl Wilhelm Scheele, in 1778. That it was given a Greek name (from "molybdos") was small wonder; many chemists had taken a look into the Greek dictionary before naming a new element. What was amazing was that "molybdos" meant "lead". Why did molybdenum go by an assumed name? Why did it borrow it from lead?

The matter had a simple explanation,

though. Ancient Greeks knew a mineral of lead, galenite, which they called "molybdena". But there also existed another mineral, molybdenite, which was a "splitting image" of galenite. This resemblance confused the Greeks and they believed they were dealing with one and the same mineral, molybdena. Chemists in other countries shared this opinion. Therefore, when Scheele discovered an unknown element in that mineral he did not hesitate to call it molybdenum.

In 1783 the Swedish chemist P. H. Hjelm succeeded in extracting the element in the form of metallic powder, but it was contaminated with carbides. It was a whole century later that it had become possible to obtain pure molybdenum.

Like many of its "fellows" in the Periodic Table, molybdenum cannot stand any impurities and "protests" against them by drastically changing its properties. Thousandths or even ten-thousandths of one per cent of oxygen or nitrogen make it very brittle. This is why many chemical handbooks printed at the beginning of the 20th century asserted that it was practically impossible to subject molybdenum to mechanical treatment. But in actual fact pure molybdenum is fairly ductile despite its great hardness, and is comparatively easily rolled and forged.

The beginning of molybdenum's "service record" dates back several centuries when the mineral molybdenite was used to make slate-pencils (curiously, even today a pencil in Greek is called "molybdos"). Like graphite, molybdenum consists of myriads of tiny flakes and their size is so infinitesimal that if 1 600 of them are piled one on top of the other, they will make a 1 600-storey skyscraper ... one micron high. It is precisely owing to these flakes that molybdenite "can" write and draw, leaving a greenish-greyish trace on paper.

In our day one will hardly come across molybdenite slates—the pencil industry has fully become the domain of graphite.



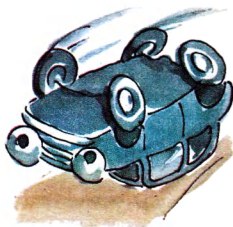
But molybdenite has found another application. Before going into that, though, we would like to tell you about an incident that took place several years ago.

A team of *Zaporozhets* automobiles were being tested on the Semfropol highway. Everything was going fine until suddenly one of the automobiles turned over at full speed, on an absolutely level stretch. Fortunately its occupants escaped unharmed. Nothing could be learned about the cause of the accident until the automobile was taken to pieces. And then it was found that one of the transmission gears which should have been freely rotating on a steel sleeve had become welded fast to it. Naturally that new "brake" acted immediately.

To prevent such accidents happening in future it was necessary to find an appropriate lubricant. This is where the ability of molybdenite to flake off came in handy. The flakes were to make a reliable lubricant on the rubbing components of the gear-box.

It is enough to dip a steel component in a solution containing only 2 per cent of molybdenite for its surface to become covered with a thin layer of an excellent solid lubricant. But this lubricant has a bad enemy—high temperature. When heated molybdenum disulphide (molybdenite) turns into molybdenic anhydride which, while being harmless to the components, does not have any lubricating ability, either. What next?

It was found that before covering the part with the disulphide it was necessary to treat it in a hot phosphate bath. In this case particles of disulphide penetrate the pores of the phosphate coating and a very thin lubricating film is formed on the surface of the component. This film is capable of withstanding colossal loads—several tons per sq cm. Bushings coated with this lubricant were tested under most strenuous operational conditions and there was not a single case of welding. Since then the *Zaporozhets* cars



have been crossing the country in all directions and back but not a single time has the notorious gear-box let the drivers down.

The development of the lubricating film is not the only good thing that molybdenite can do for a steel surface. For example, if a cutting tool is treated by molybdenite, it will become stronger and more durable. This marvellous property was immediately made use of by hairdressers. But back to molybdenum.

Owing to its high melting point and low expansion coefficient molybdenum is widely used in electrical engineering, radioelectronics and high-temperature engineering. The tungsten filament holders in a common electric lamp are made from molybdenum, just as many components of electron and X-ray tubes. Molybdenum coils heat powerful vacuum resistance furnaces where very high temperatures are developed.

Extremely valuable composite materials have been developed in the Institute of Problems of Materials Study under the Ukrainian Academy of Sciences. Ductile metals, such as aluminium, copper, nickel, cobalt or titanium are taken as the base material while the high-strength metals like tungsten and molybdenum are used as reinforcement fibres taking upon themselves most of the tensile load. The strength of tungsten- or molybdenum-reinforced nickel and cobalt increases almost threefold. Ti-

tanium reinforced by molybdenum is twice as strong as common titanium.

Several years ago American researchers developed an unusual type of glass: it changed its colour depending on the time of day, turning blue in sunlight and becoming transparent at night. This effect was produced by additions of molybdenum either in molten glass or by glueing a thin transparent film in between two layers of glass.

Molybdenum compounds have many uses: they increase the covering power of enamels; molybdenum dyes are used in ceramics and plastics industries, as well as in tanning and in the fur and textile industries; molybdenum trioxide is applied as a catalyst in the cracking of oil and in other chemical processes.

As you see, molybdenum has plenty to do. But we have not said a single word about its main job yet—all that has been discussed is its side-lines, so to say. At the beginning of this story we mentioned molybdenum as a loyal ally of iron. This is the aspect we would like to take up now, as more than 90 per cent of molybdenum produced in the world is consumed by the special steel industry. In Russia the first molybdenum-containing steel was smelted in 1886 at the Putilov Plant in St. Petersburg. But it must be said that the use of this element as a means of improving the quality of steel has a much longer history.

For a long time futile attempts had been made to unravel the secret of the extraordinary sharpness of Samurai swords. Generation after generation of metallurgists failed in all attempts to make steel which would be like that used in olden times to make side-arms in the Land of the Rising Sun. The first successful attempts were made by the great Russian metallurgist Pavel Anosov (1799-1851). It was established that the mysterious steel contained molybdenum which simultaneously improved the metal's hardness and

ductility, even though an increase in hardness, as was commonly believed, usually resulted in an increase in brittleness.

The combination of hardness and ductility is essential for armour steel. The armour on the first British and French tanks that appeared on the battlefields of the First World War in 1916 was manufactured from hard but brittle manganous steel. Alas, German shells went through those massive 75-mm-thick shields as easily as through butter. But it was enough to add only 1.5-2 per cent of molybdenum to make the tanks impregnable, despite the fact that the thickness of the armour sheet had been reduced to a third of what it had been before.

How was that magic transformation to be explained? The point is that molybdenum retards grain growth in the process of crystallization of steel, hence, makes it fine-grained and homogeneous, all of which ensures the metal's fine quality. Most alloy steels suffer from tempering brittleness. But molybdenum-containing steels do not fear this "complaint", owing to which they can be subjected to heat treatment without any danger that internal stresses may develop. Molybdenum considerably increases steel hardenability. Such steel is also characterized by considerable strength at high temperatures and high creep resistance. Tungsten affects steel in much the same way, but molybdenum's influence on the strength of steel is much greater: 0.3 per cent of molybdenum can replace 1 per cent of tungsten—a more expensive metal.

However, armour is not the only application of molybdenum steel. Cast from this steel are gun barrels, aircraft and automobile components, steam engines, turbines, cutting tools and razor blades. Molybdenum also improves the quality of cast iron by increasing its strength and wear resistance.

The high alloying capacity of molybde-



num is explained by the fact that its crystalline lattice is identical with that of iron; the radii of their atoms are also roughly similar. And "kindred souls" can always find a common tongue. But molybdenum is close not only to iron. Its alloys with chromium, cobalt and nickel are characterized by a high resistance to acids and are used in the manufacture of chemical apparatus. Some alloys of the same elements have a high resistance to rubbing. Alloys of molybdenum with tungsten can replace platinum; alloys with copper and silver go into the manufacture of electric contacts.

Liquefied gases especially nitrogen, are widely used in refrigerating engineering. Terrible frost—nearly 200°C below zero—is needed in order to keep it in its liquid state. Under such a temperature ordinary steel becomes as fragile as glass. Containers for the storage of liquid nitrogen are made from a special cold-resistant steel. However, this steel too had one drawback which it had proved impossible to eliminate for a long time. This drawback was that its welds were not strong enough until molybdenum was added to the metal. Formerly the additions used during welding included chromium which, as it was found, caused the welds to crack. Research showed that molybdenum prevented cracking. As a result

of numerous experiments it was finally established that the addition of 20 per cent of molybdenum was an optimal addition, enabling the welds to withstand minus 200°C frost as easily as the steel itself.

Not long ago metallurgists developed a new remarkable alloy, comochrome, from cobalt, molybdenum and chromium, which proved to be an excellent material for human "spare parts". It is absolutely harmless for the organism and is willingly applied by surgeons when damaged joints have to be replaced.

Agriculture is another field where molybdenum has found application. In 1965 a group of Soviet researchers was awarded the Lenin Prize for a study of the biological role of trace elements and their use in agriculture. Introduced in microscopic doses in soil or in animal feeds some elements literally work magic. Molybdenum is one of these miracle workers. Infinitesimal quantities of this element substantially increase the yield of many crops and improve their brands. Leguminous crops are particularly strongly influenced by molybdenum. The yield from peas processed by ammonium molybdate is 30 per cent greater than usual. Molybdenum concentrations that are formed in the plants' tubers improve assimilation of

nitrogen from the atmosphere—a process absolutely essential for plant development. Molybdenum is conducive to increase in the content of proteins, chlorophyll and vitamins in plant tissues. It is an interesting fact that this element is pernicious for some weeds.

Extraordinary research was carried out at Osaka University in Japan. Scientists there analyzed, by means of most sophisticated equipment, some remains of burnt human hair and arrived at the conclusion that its colour depended on the presence of traces of certain metals. For example, fair hair was rich in nickel and golden in titanium. If redheads feel like complaining about their hair, they must blame molybdenum—it is precisely this element, according to the Japanese researchers, that gives the hair its red colour. There is every reason to suppose, therefore, that had there really existed a “redheaded league”, so expertly dealt with by Sherlock Holmes, the symbol of molybdenum should have adorned its emblem.

Unfortunately, this element sometimes becomes involved in affairs that can never be regarded as beneficial to mankind. The “negative” aspects of molybdenum were

revealed by Soviet scientists after they had returned from a lengthy marine expedition.

The expedition on board the *Mikhail Lomonosov* set out from Vladivostok at the end of 1966. Its task was to study the level of radioactive contamination in various sections of the World Ocean. Month after month the boat was plying water expanses and all the time the sensitive Geiger counters were “doing duty” on its board. They were like frontier guards ready to intercept radioactive “guests” any moment.

One day the boat was preparing to cross the equator at one of the most desolate regions of the Pacific Ocean. Day and night the blades of the ventilator on board rotated with great speed and directed thousands of cubic metres of sea air to the filters capable of catching dust particles as small as a few hundredths of one micron. At certain intervals the filters were burned together with the dust they had collected. The radioactivity of the ash was determined by means of highly sensitive instruments. Suddenly the Geiger counters registered unusual “excitement”: the ashes contained the radioactive isotopes molybdenum-99 and neodymium-147. These isotopes have a very short life (the half-life of the molybdenum-99 is only 67 hours). The scientists’ measurements and calculations revealed that the “unwelcome guests” were produced on December 28, 1966. Indeed, as the New China News Agency reported, China carried out a nuclear test on that day, and within a few days the radioactive particles had been blown over an area of thousands of miles around.

But it must be noted for the sake of justice that molybdenum plays a very modest role in this dangerous game. We hope that nuclear tests are going to be banned completely, and then molybdenum will be seen no more in this unseemly role but will be engaged strictly in serving humane purposes. And you have already



seen that mankind does need molybdenum for many purposes and in large amounts. What are the reserves of this element on the planet?

The share of molybdenum in the earth's crust is 0.0003 per cent. In the extent of its natural occurrence it holds a modest place in the Mendeleyev Table—in the fourth dozen. But still molybdenum deposits are found in many parts of the world.

While at the beginning of this century molybdenum production was only a few tons, it went up almost 50 times already during the First World War (armour was in great need!). Afterwards the output of molybdenum ores dropped sharply but around 1925 a fresh rise in production was registered. By 1943 (i.e. during the Second World War) it reached its maximum—30 000 tons. Hence, the name “war metal” as this metal is sometimes referred to.

In the Soviet Union a large deposit of molybdenite was discovered in 1934 by Vera Flerova, a geology student, in the Baksan river canyon in North Caucasus. That was a remarkable event in the history of the national rare metals industry. Two years later a mine was already under construction there. Unfortunately, Vera Flerova was not fated to see the town of Tyrnauz which owed its birth to her, springing up high in the mountains, on the spot she had discovered. Driven by her constant thirst for exploration, this courageous young woman had a fatal incident in the mountains, in 1936. One of the squares in Tyrnauz and a mountain peak bear her name today. And away from the busy thoroughfares, on a lonely mountain slope there stands a modest obelisk in commemoration of Vera Flerova. A little away from it and above, trolleys carrying the wonderful molybdenite ore are slowly moving along steel wire ropes, as though symbolizing her feat.

Molybdenum ores are for the most part processed into ferromolybdenum used in



the metallurgy of high-grade steels and special alloys. The first industrial attempts to produce ferromolybdenum were made at the end of the 19th century. In 1890 a process whereby this alloy was made by reducing molybdenum oxides was developed. But that was all that was done in the way of ferromolybdenum production in pre-revolutionary Russia. In 1929 S.S. Shteinberg and P.S. Kusakin obtained an alloy containing 50-65 per cent of molybdenum by a silico-thermal process. The successful experiments carried out by V.P. Yelyutin in 1930-31 made it possible later to introduce this process in metallurgy.

However, the technology needs pure molybdenum, as well. But it was a long time before articles from pure molybdenum could be made. Why? Wasn't the method of producing comparatively pure molybdenum powder known since long in the past? The reason was molybdenum's high melting point which prevented metallurgists from transforming the powder

into solid metal by smelting. Other ways had to be found. In 1907 the first molybdenum filament was produced in laboratory conditions. For that molybdenum powder was mixed with a sticky organic substance and drawn through a die. The sticky thread which the experimenters now had was placed in a hydrogen atmosphere and current was passed through it. As could only be expected, the thread warmed up and the organic substance burned away, while the metal particles melted into a thread (hydrogen was needed to prevent molybdenum from oxidation).

Three years later a patent was issued on the production of high-melting metals in the process of powder metallurgy which is still in use today. Metallic powder is pressed, melted, then rolled or drawn and the strip or wire is ready for use.

The production of molybdenum wire was started in the Soviet Union in 1928. Three years later the Moscow Electrozavod Plant was turning out as much as 20 million metres of it.

During the last few years molybdenum has also begun to be produced by vacuum arc melting and zone and electron-beam melting.

We have already mentioned the fact that the reserves of molybdenum in the earth's crust are not large. Perhaps they are going to be exhausted after some time and humanity will be faced with the problem of finding new sources of this valuable metal.

So far there is no cause for worry over the fate of the future generations. For it is a fact that the seas and oceans also contain enormous reserves of many elements. If the sea treasures were to be shared among all the inhabitants of the planet, then all people would become fabulously rich. Suffice it to say that Neptune's "coffers" conceal something like three tons of gold per earthling, to say nothing of other treasures. Quite a goldmine, isn't it? As for molybdenum, we would have about 100 tons each.

Mankind is still trying to find a key to the blue "coffers" of Neptune and the day is not far off when it succeeds.

OF A NOBLE ORIGIN



Alexander the Great is forced to retreat.—Cyrus' "sacred vessels".—Silver horse-shoes.—The second oldest profession.—The rouble is born.—Royal counterfeiters.—The Russian boyars' bright idea.—The Mint celebrates its 250th anniversary.—Vice Governor receives instructions.—The secret of the Nevyansk tower.—Family silver.—Count Orlov's dinner service.—The art of Novgorod silversmiths.—In a photographer's studio.—A trapped cyclon.—A mirror is no luxury.—Sinking with the Thresher.—A champion metal.—Some history dealing with geography.—The Queen blesses a pirate.—Merry-making on shipboard.—On the sea floor.—A fisherman's blunder.—Diver's find.—Phipps stamps his feet.—Dream coming true?

Winning one victory after another, the irrepressible army of Alexander the Great was marching to the east. Behind lay the subdued Persia and Phoenicia, Egypt and Babylonia, Bactria and Sogdiana. In 327 B.C. the warriors invaded India and it seemed there was no force that could stop the great commander. But suddenly the Greek army was struck by an outbreak of a mysterious gastrointestinal disease. Exhausted and suffering, the men rose demanding to be sent home. Anxious though he was to follow the road of conquest, Alexander was forced to turn back.

There was one inexplicable fact about that episode: the Greek military commanders fell victim to the mysterious disease far less frequently than their men,

although they were sharing all the hardships and privations of camp life.

More than 2000 years had passed before scientists could find an explanation. And it seems the whole point was that the soldiers used tin cups and their superiors, silver ones.

It was proved, remarkably, that silver dissolved in water killed many harmful bacteria. A few thousand-millionths of one gram of silver are enough to purify a litre of water. It was perfectly natural, therefore, that the army top using silver cups were much less exposed to disease than the men under their command.

The ancient historian Herodotus writes that in the 5th century B.C. the Persian King Cyrus, when on the march, kept his water in "sacred silver vessels". Indian religious books describe how water was purified by immersing white-hot silver in it. In many countries silver coins were traditionally thrown into wells during consecration ceremonies.

Perhaps the purifying action of silver can be considered the oldest "occupation" of this metal, although it is also true that sometimes it was used for downright ridiculous purposes to satisfy the whims of those in power. For example, the Roman Emperor Nero, a notorious spendthrift, had thousands of his mules shod with silver. But that was no more than a minor episode in the history of this metal.

The second oldest profession of silver, its "life's work", was to serve as a value standard—to play the role of money. Romans began to mint silver coins in 269 B.C. or 50 years before gold ones. In Russia locally made coins appeared much later. Still preserved are silver coins (*srebreenniki*) of the Russian Prince Vladimir made between the 10th and 11th centuries. One side of the coin had a stamp showing Vladimir sitting on the throne and the other, his family emblem. The inscription said, "Vladimir on the throne and this is his silver."



In the 12th and 13th centuries Russian coins disappeared from circulation. By that time the lands which had been united around Kiev to form Kievan Russia, had again disintegrated, and the minting of the single national coin was stopped. Silver ingots began to be used as money once more. Historians describe this period as "coinless".

It was then, in the 13th century, that the rouble came into being—a silver bar weighing about 200 grams. In some old literary sources this silver piece is also called a rouble *grivenka* or *grivna*. This is how the *grivenka* was made: a long narrow silver bar was cast and then cut into pieces with a point-tool. One piece was one rouble *grivna* or simply a rouble.

The Mongol-Tatar invasion detained the minting of Russian money still longer. The Golden Horde issued its silver coin—*dirgema* or *denga* (in Tatar *denga* means "jingling"). Gradually the Tatar *denga* became the Russian *dengi*, money.

It was only in the middle of the 14th century when the Russian people had succeeded in undermining Mongol-Tatar power that the minting of national coins was begun.

In 1534, during the reign of Yelena Glinskaya, the mother of the future Ivan the Terrible, a single Russian national monetary system was introduced. Small silver coins had a picture of a horseman with a sword and they were called *mechevye* (*mech* is in Russian a sword). Heavier silver coins were with a horseman holding a spear and they were called *kopeinye* (*kopye* is a spear), from which the modern word "kopeck" was derived.

Although it is difficult to get at the actual truth now, but probably it would be correct to suppose that the first counterfeiters appeared together with the first money. Even some royalty were guilty of counterfeiting. Philip IV the Fair who ruled over France at the end of the 13th and the beginning of the 14th centuries is

referred to in some historical sources as Philip the Counterfeiter. In order to build up his personal wealth this monarch shamelessly reduced the weight of gold and silver coins or replaced some of the noble metal with copper or tin. The great Dante included Philip IV among the other sinners in his *Divina Commedia*.

A case when the issue of counterfeit money was attempted at state level dates to the 17th century. The year was 1654. The burdensome war with Poland had emptied Russia's treasury, but more money was needed all the time. Tsar Alexey Mikhailovich raised taxes, large as they were, but the impoverished people could not pay them. Fedor Rtishchev, a *boyarin*, devised a measure which he thought would enrich the treasury but which led to damaging consequences instead.

At that time silver money was in circulation in Russia. Since the country had no silver of its own then, coins were minted from ... foreign money pieces, usually joachimsthalers (coined in the Czech town of Joachimsthal), called by Russians *yefimki*. The Latin inscription was removed from them and replaced with a Russian one. Advised by Rtishchev and other boyars, the tsar decided to make profit by ordering that one-rouble stamps be put on the *yefimki* that cost the treasury 50 kopecks each. Simultaneously the *poltinnik* (50 kopecks), *polupoltinnik* (25 kopecks), *grivennik* (10 kopecks), *altyn* (3 kopecks) and *kopeika* (one kopeck) were to be made from cheap copper, but valued as silver ones. The royal financiers had calculated that the measure was to bring four million roubles to the treasury—10 times more than all the annual taxes amounted to. The thought of all that money went into the tsar's head and he ordered the new coins to be made "in a hurry, day and night and with great diligence so that much money can be had soon."

Soon the cheap coinage had flooded



Russia. But money has its own laws and even monarchs are powerless to govern them. If there is more money in circulation than there should be, its buying power declines and prices for all goods go up. And that was exactly what happened in the Russian State. Common folk were soon to feel the consequences of the tsarist reform: the prices of bread and other products were rising fast, while traders accepted only silver as payment. But where was it to come from after the bulk had settled in the tsar's coffers? Famine struck the land, the people's endurance was wearing thin. In 1662 an uprising which went down in history as the "copper riot" broke out in Moscow. It was ruthlessly suppressed, but nevertheless the people had their way: copper money was taken out of circulation and replaced by silver.

During the rule of Peter I money was mainly minted by the Moscow Mint which was situated in the region called Kitai-

Gorod. In 1711 the Senate decreed that "silver money is to be made only by one mint, the one in Kitai." In 1724 a new mint was set up in St. Petersburg by a royal order. Today it is the Leningrad Mint which recently was 250 years old.

Peter I took energetic measures to increase the production of gold and silver. But despite the impressive progress made then, Russia was to buy these metals abroad for a long time yet. History has preserved some documents proving this fact. For example, in 1734 the government instructed the Vice-Governor of Irkutsk to buy a big consignment of silver in China.

At about the same time the ore explorers of Akinfy Demidov (the Demidovs were a powerful dynasty of iron-manufacturers in the Urals) found a deposit of silver ore. Under the law of that time silver ore, wherever and by whomever found, was the property of the imperial court. But Demidov had no wish of parting with his treasure. He began to coin his own money which was just like government coinage with the exception that it contained more silver. Most likely that was the only case in history where counterfeits were more valuable than genuine money.

Legend has it that in Nevyansk, the Demidovs' estate, there was an underground mint with slaves chained to the walls in a basement floor of a tall tower, minting counterfeit money day and night. It was a terrible prison which no one could ever hope to leave: never was the government to know about the secret. However, all precautions notwithstanding, a rumour about the Nevyansk tower had leaked out and reached the capital. At first it was only a vague rumour and even Empress Anna Ioanovna did not risk spoiling her good relations with the uncrowned king of the Urals. But according to one story, when the Tsarina accepted some brand new silver coins from Demidov one day—her win from a card game with him—she



suddenly asked him: "Are these of your or my making, Nikitich?" Demidov got up from the table, spread his arms, bent his head humbly and answered with a smile: "We are all yours, your Majesty, and I'm yours and all that is mine is yours too!"

Soon after that an incident occurred that put an end to the underground mint. One of Demidov's craftsmen, terrified by his master, managed to flee from Nev'yansk to St. Petersburg. The minute Demidov learned about it, he sent a pursuit party with orders to seize and kill the man or, in case of failure, rush to the Empress with the "good news" that a silver deposit had been discovered in the Urals.

The fugitive was not caught and the "good news" about the silver reserves had to be reported at the court. An acceptance commission was dispatched to Nev'yansk. Two days before its arrival Demidov ordered the sluices connecting the tower basement with a nearby lake to be opened and all the workers in the mint—the main witnesses of his crimes—remained under water forever.

Silver has been used in jewelry since time immemorial. It has always been prestigious to own silver services, cups and goblets, powder- and cigarette-cases and snuff-boxes. Silverware was especially valued by Russian and French aristocracy for whom their "family silver" was something like a visiting card speaking of its owner's noble origin and wealth. Count Orlov had a unique silver service which consisted of 3275 articles into which about two tons (!) of pure silver had gone.

Silversmiths of Novgorod were famous throughout the land and far beyond for their inimitable craft of embossing and engraving. Their cups, bowls and vessels enraptured contemporaries by the beauty of design and finish. According to some historical sources, there were nearly one hundred master silversmiths working in 16th century Novgorod, as for smaller craftsmen who specialized in making crosses, rings, ear-rings, and other personal ornaments, they could not be even counted. The Novgorod silverware is today on display in the Armoury, the State History

Museum and the Russian Museum in Leningrad.

While naturally retaining its role of a jeweller's and craftsman's metal, silver today has many more serious things to do as well. Ever since Daguerre, the French painter and pioneer photographer, developed a process by which permanent pictures could be produced on sensitized materials in 1839 silver has been inseparably linked with photography. The main part in this process is played by an extremely thin layer of silver bromide deposited on photographic film or paper. Under the action of light silver bromide disintegrates, with the bromide bonding chemically with the gelatine in the layer and silver precipitating in crystals so tiny that they cannot be seen under an ordinary microscope. The rate of disintegration of the silver bromide is directly proportional to the intensity of light to which it was exposed.

Further processing (development and fixation) produces a negative image which becomes a positive picture when printed. Great though the advance in photography has been during its history of more than a hundred years, it is still inconceivable without silver and its compounds.

Scientists have found a fascinating job for silver iodide: it is an effective help in fighting tropical cyclonic storms. In order to reduce the devastating force of a storm it is necessary to stretch it, as it were, that is, to increase its diameter. This is what silver iodide does, owing to its ability to condense atmospheric moisture into rain drops.

This method was tested for the first time some ten years ago on a hurricane. A "screen" of silver iodide suspension 10 km high and 30 kilometres long was put up on its way by means of planes. Having struck against the screen, the "unsuspecting" storm rolled it and swallowed it up. The same instant the cloudy wall around its central section, the so-called

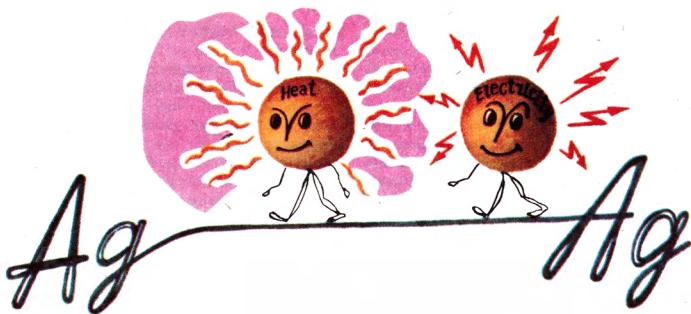
hurricane eye, fell apart spilling rain and the force of the wind dropped sharply. True, it was not "taken aback" and began forming another cloud wall, but it was much bigger in diameter, hence moving much slower than before. The destructive effect of the "silver-sprinkled" hurricane had grown considerably weaker. It is noteworthy that impressive as the size of the screen was, it had required only a few metric tons of silver iodide.

Silver has been used in mirror making from the middle of the last century. A sheet of polished glass silvered at the back has the greatest reflecting power of all the known metals. It is indispensable not only in everyday life but also as the doctor's tool and as an essential component of telescopes, microscopes and other optical instruments.

No other metal is as good a thermal and electrical conductor as silver. Silver wire is used in the most sensitive physical instruments; it is from silver that vital terminals in various relays are made and it is also with silver that important components of radio systems are soldered.

The numerous automatic devices, rockets and submarines, computers and nuclear installations, means of communication and signalling systems—none of these can do without contacts. During its life every one of them is brought into operation millions of times. In order to be able to withstand such colossal strain, the contact must be wear-resistant, reliable in exploitation and must meet a number of specifications. The contacts are usually made from silver. Specialists are well satisfied with this metal—it does its difficult job perfectly. But silver displays even more valuable properties once rare-earth elements are added to it. The life of contacts made from such silver increases several times over.

According to Western mass media, the nozzles of some jet engines are manufactured from foam tungsten saturated with



silver. Probably not many people know that the US submarine *Thresher* which so mysteriously disappeared in the ocean waves in 1963 carried several tons of silver that had gone into the manufacture of her accumulators.

Silver is so ductile that it can be beaten into a transparent leaf only 0.00003 centimetres thick, while a one-gram grain of it can be drawn out into a wire nearly two kilometres long.

Pure silver is a beautiful white metal and its Latin name "argentum" comes from the Sanscrit "argenta" meaning "light-coloured".

While we are on the subject of names, we would like to tell you about some remarkable facts associated with some of them. The map has often helped discoverers to find a name for a new element. Take a look at the Mendeleyev Table and you will see ample proof: germanium, francium, europium, americium, scandium and californium. Such cases are quite common, but a case when a big river and even a whole state were given a name in honour of a metal is probably unique. The metal was silver and this is what happened more than 400 years ago.

At the beginning of the 16th century

Juan Diaz de Solis, a Spanish seafarer, discovered a big river flowing into the ocean off the eastern coast of South America. Not overburdened with modesty, he gave the river his own name. Ten years later Captain Sebastian Cabot happened to sail up the same river and was amazed at the amount of silver his men had seized from the local population. And he called it Rio de la Plata (in Spanish silver is la plata). Later it became the name of the whole country. But at the beginning of the 19th century Spanish rule was overthrown and in order to forget their sad past the people of the country changed the Spanish "La Plata" into the Latin "Argentina".

There is another story connecting silver with a geographic name. In 1577 a fleet of several ships under the newly-fledged Admiral Francis Drake sailed from the British coast. He had been honoured with the high rank by Queen Elisabeth for his many years of faithful service as a ... pirate. And the purpose of his new voyage secretly blessed by Elisabeth was the looting of cities owned by Spain on the Pacific coast of South America. Elisabeth and her entourage had become "shareholders" of the "Drake and Co" hoping to

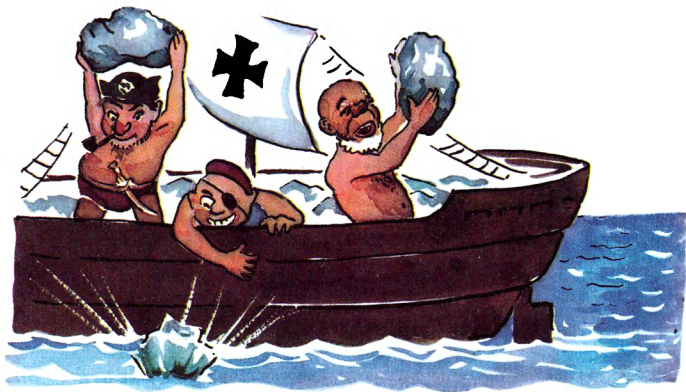
make fortunes out of the notorious "iron" pirate's adventures.

For several months had Drake's ships plied the seas and oceans diligently "working" to the Queen's good. In his many battles Drake had lost four out of his five ships, but the *Golden Hind*, his flag-ship, continued to terrify the population of coastal towns. At dusk one day the pirate turned up near Callao where roughly 30 Spanish ships were moored. Drake, it must be admitted, lacked nothing in courage: his *Golden Hind* entered the harbour and stood there the whole night side by side with the enemy vessels. The Spanish sailors had had enough rum to drink to forget everything and were having a marvellous time on decks long after midnight. Some of them were loudly discussing other ships that had left harbour not long before, loaded with precious cargos. According to them, the royal galleon *Cacafuego* was literally overflowing with treasure. Hearing about it, Drake

immediately weighed anchor and hurried in pursuit.

It was for good reason that Drake's ship was called the *Golden Hind*: few ships could contest its speed. Very soon, near the coast of Ecuador, Drake boarded the *Cacafuego*. This is how one of Drake's associates described the developments that followed: "Next morning inspection and assessment of the cargo began and it lasted for six days ... There we found gems, 13 cases of silver coins, 80 pounds of gold and 26 casks of unstamped silver ... At the end of the sixth day we said goodbye to the captain and, somewhat unburdened, he hurried to Panama and we headed for the open sea."

The far-sighted Drake realized that the *Golden Hind* was far from her journey's end and that the Spaniards might yet try to get their treasure (plundered in South America) back. But overloaded as she was, the ship could not maintain her high pace. Was Drake to listen to common sense or



give in to avarice? Drake's decision was correct: 45 tons of unstamped silver went overboard. In memory of the lost treasure the pirate named a nearby island La Plata.

Naturally this was not the only case where silver, gold and other valuables ended up on the seabed. During the ages-old history of seafaring thousands of ships were wrecked and sunk, sometimes taking with them countless treasure down the blue abyss. This is a fact that has long since deprived numerous treasure seekers of their peace of mind.

The sea is unwilling to give up its riches but people are tireless in attempting to lay their hands on them.

In 1939 an old fisherman salvaged a few oblong stone blocks from shallow water south-east of Pigeon Keys, an island off the Florida coast. He used them for some time as ballast in his boat but then threw them out. One block was left in the boat accidentally and the old man began to use it as an anvil on which he straightened nails. Two years had passed. From the many hammer blows and scratches the stone seemed to become softer and was beginning to show a lustrous surface. It was then that it had dawned on the fisherman that his "anvil" was a bar of pure silver. But instead of rejoicing the old man was desperate: what an old fool he was to have thrown overboard with his own hands the treasure God had sent him!

But not all was lost, he thought to himself, and put to sea, to the place where he had seen numerous such "stones" with his own eyes. The fisherman searched far and wide, through all the bays, but could never find the inconspicuous ridge of reefs where a galleon had met its end a few hundred years ago.

McKee, an American diver, was more successful. In May 1949 he was making an underwater survey in the vicinity of the coast of Florida, not far from the reefs of Key Largo. One day he noticed what

looked like a shipwreck at a depth of 20 metres. He made a careful inspection and discovered several guns, an anchor and three heavy oblong blocks. McKee's curiosity aroused, he raised them to the surface and was rewarded handsomely: the bars turned out to be pure silver stamped NATA. Specialists at the Washington historical museum established that the stamp had belonged to an old silver mine in Panama and that the ship McKee had discovered was one of the 14 Spanish galleons wrecked in the terrible hurricane that swept the area in the spring of 1715.

Both the Florida fisherman and McKee became treasure hunters unintentionally. As happens much more often, underwater treasure hunts are conducted according to plan. But this does not mean that they fail less frequently than unorganized searches. Sometimes success comes when least expected. That was exactly the case with one William Phipps at the end of the 17th century who had been instructed by King James II of Britain to try to recover the treasure of a Spanish galleon which had sunk in the vicinity of the Bahama Islands.



Days, weeks and months had passed but the Phipps expedition was unable to find the wreckage. When a whole year had gone by, Phipps was ready to admit defeat. He called his assistants and announced the end of the search. Uttering his last words, he stamped his foot under the table in helpless fury and the same instant something rolled from under the table. It looked like a coral outgrowth but had a suspiciously regular form. Phipps struck it with an axe and saw a box of hard wood inside. Another blow and gold and silver coins poured to the floor.

It turned out that the "piece of coral" had been found and thrown under the table by one of the divers, a Red Indian. Several divers were immediately dispatched to explore the place where the "coral" had been found and they soon brought back a dozen similar objects.

Work got under way. Phipps himself went down several times in a diving bell. In three months the expedition recovered 30 tons of silver, a substantial amount of gold and numerous cases with coins. The total value of the treasure was 300 000 pounds (more than one million by the present rate of exchange).

Not long ago silver found on the sea floor was the cause of an international dispute. Everything began in 1972 when Robert Marx, an American archaeologist of the Seafinders Company which engages in marine treasure hunting, discovered a sunk Spanish galleon 45 miles north of the Bahamas. A few days later work was in full swing on the spot in preparation for the recovery of its cargo. Soon it was established that the ship sank in 1656 with a large consignment of silver and other valuables worth about 2 000 000 dollars.

It was expected that the treasure would be intact in the ship's hold or cabins. Indeed two or three weeks later the first batches of the treasure began to be raised to the surface. The company bosses were rubbing their hands in joyous anticipation

when unexpected difficulties arose: learning about the find, the Bahama administration claimed the silver and everything else to itself. Work had to be stopped while the conflict assumed such proportions that the US State Department had to step in. Its spokesman declared that the galleon was not in the territorial but in international waters and for that reason the Bahama government had no right to its "contents". The argument is still going on and it is hard to say where it will end.

Despite the fact that finds are very rare, the army of underwater fortune seekers is constantly growing. It goes without saying that the modern scuba diver has much greater chance of being successful than, say, Phipps' divers who had only their lungs to count on, but still the ocean is reluctant to yield its secrets.

Silver troves are found on the surface as well. For example, not long ago a treasure of 1 000 Arab silver coins was found in Gotland, a Swedish island, under quite extraordinary circumstances. The lucky one was ... a rabbit, a common grey rabbit which wanted to dig itself a hole in the country near the small town of Bjurse. When the animal was half-way through its "construction work" it was showered with metal discs and it must have been with the greatest difficulty that it threw them out of its hole. Soon the coins were discovered by archaeologists and were sent to the Stockholm Historical Museum. This is what specialists there were able to surmise.

Once upon a time Gotland was a rich trading centre of Europe frequented by merchants from many countries. Hundreds and thousands of silver coins changed hands there or settled in the chests of fortunate traders. Sometimes they got into the hands of the vikings who visited the island for their own ends. According to a legend, the treasure found by the rabbit was buried in those ancient times by a viking chief Staver. For many decades had the local population believed the story

that about 150 years ago a drunken Gotland peasant dreamed he was visited by the devil who gave him a handful of silver coins from Staver's treasure and told him in strict confidence that five generations from then people would find the whole treasure which the powerful viking had "put up for a rainy day".

It is hard to say if the legend had any

real background, but what is truly incredible is that exactly five generations later the treasure was discovered at the very spot indicated in the legend. If this is true, it would be interesting to know why the devil had withheld from the peasant the remarkable fact that the most important part in the discovery would be played by a rabbit.

“HARD” BUT . . . SOFT



Expedition meets with disaster.—“Tin plague”.
—Tricks of the Russian winter.—Loss of buttons.
—Witches are to blame for everything.—Atoms
allow themselves more space.—A “plague vaccine”.—
The “cry” of tin.—No competitors.—A tin soldier’s
fate.—Hard or soft?—Find in a grave.—Hephaestus
equips Achilles.—The Aztec money.—Julius Caesar
can give confirmation.—The King was wrong.—A
weighty exhibit.—Explorations on Cape Svyatoi
Nos.—The Ford Motor glass.—A sun trap.—Failure
of a “bank operation”.—Tin sacrifices itself.

In 1910 Captain Robert Scott, the famous British polar explorer, fitted out an expedition to the South Pole, at that time still a terra incognita. For many weary a month had the expedition been making its painful progress through the lifeless ice deserts of the Antarctic, leaving behind small caches of food and kerosene to take care of their needs on the way back.

At the beginning of 1912 the expedition had finally reached its destination but to the men's great disappointment they found a note there which made it clear that they had been preceded by the Norwegian explorer Roald Amundsen one month earlier. However, Captain Scott's worst misfortune was yet to come. On the way back it was discovered at the very first cache that the expedition was left without kerosene: the cans that had been stored up there were empty. The people, exhausted, freezing and hungry, could not warm themselves up nor prepare anything to eat. It was with the greatest difficulty that they managed to get to the next cache, but there too the cans were empty—the kerosene had leaked out. Powerless in the polar cold which was made worse by terrible blizzards that had begun by then, Captain Scott and his friends soon died.

What was the reason for the mysterious disappearance of the kerosene? Why did the expedition so carefully planned end so tragically? What was Captain Scott's mistake?

It was quite simple: the kerosene cans had been soldered with tin. The explorers must have been ignorant of the fact that at freezing temperatures tin "catches a cold", first losing its lustre and becoming dull grey and then disintegrating into powder. This phenomenon—"tin plague"—was what sealed the fate of the expedition.

Meanwhile it is a fact that tin's predisposition to "disease" had been known long before those sad events. It was noticed as early as the Middle Ages that tinware "developed" ulcers when exposed

to frost, and that the "ulcers" gradually became larger and spread, finally reducing the metal to powder. It was known, besides, that once a "sick" tin plate came into contact with a "healthy" one the latter would soon cover with grey spots and also "perish".

At the end of the last century a train carrying bars of tin was sent from Holland to Russia. When the cars were unsealed in Moscow they appeared to contain some grey and useless powder—it was Russian winter playing a wicked trick on the buyers of tin.

At about the same period a well-equipped expedition set out for Siberia. It seemed everything had been taken care of to ensure its success, except one thing: tin dishes had been taken. The result was that after a while spoons and bowls had to be carved from wood if the expedition was to go any further.

At the very beginning of this century a shocking incident occurred at an army depot in St. Petersburg: an audit there discovered, to the horror of the quartermaster, that all tin buttons had vanished from the soldiers' uniforms and



the boxes that were supposed to contain such buttons were full of a grey powder. The quartermaster was desperate, expecting that he would be accused of theft and sent to a hard labour camp. But the poor fellow was saved by the report sent in from the chemical laboratory to which the contents of the boxes had been sent to be analyzed. It said: "The substance sent by you is doubtlessly tin. Apparently we are dealing here with the chemical phenomenon known as 'tin plague'."

What are the processes that cause tin to disintegrate? In the Middle Ages churchmen believed that "tin plague" was caused by witchcraft and many innocent women were burnt at the stake as witches. Although the absurdity of such beliefs became clear as science developed, it was still impossible to find the real cause for a long time yet.

It was only after metallurgists began to be aided by X-rays, enabling them to take a look inside the metal and study its crystalline structure, that the witches were fully rehabilitated and a genuinely scientific explanation to the mystery was found. It seems that tin (and other metals for that matter) can have different

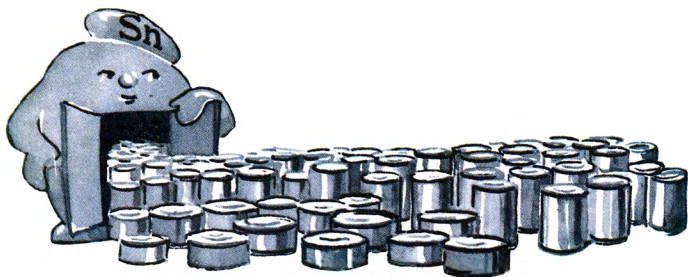
crystalline forms under different circumstances. At room and higher temperatures the most stable modification is white tin—a malleable metal. At a temperature below 13°C the crystalline lattice of tin becomes rearranged, so that more space is left between its atoms. A new modification—grey tin—is formed. It loses the properties of metal and becomes a semiconductor. The internal stresses that emerge in places of contact between the different crystalline lattices cause the material to crack and disintegrate into powder. One modification turns into the other the faster, the lower the temperature of the medium. The process has the fastest rate at minus 33°C. Thus, one can easily imagine what happens to tinware when it is exposed to severe frosts.

But, the reader may argue at this point, we know that tin is widely used to solder radioelectronic (especially semiconductor) apparatus and that wires and various components are also tinned which means that this metal gets to the Arctic and Antarctic and to other cold parts of the world. Are we to understand that the instruments and apparatus break down soon? Certainly not. Scientists have learned to give tin "injections" making it immune to "tin plague". One "injection" substance is bismuth the atoms of which supply the tin lattice with additional electrons stabilizing its state and completely ruling out the possibility of tin "catching a cold".

Pure tin has one queer property: when bars or plates of it are bent they give out a characteristic crackling noise or "cry" of tin. This sound originates from the friction between crystals when they are dislocated and deformed. But alloyed with other metals tin "holds its tongue".

Almost half the tin produced in the world today is used for the manufacture of tin plate from which cans are made. This is where the good properties of tin are fully





revealed: its chemical resistance to oxygen, water, and organic acids, as well as the complete harmlessness of its salts for the human organism. In this field tin has practically no competitors. It is for good reason that it is called "canning metal". A very thin layer of tin plate enables people to preserve millions of tons of meat, fish, fruits, vegetables, etc.

In the past molten tin was used for tin plating: a cleaned and degreased sheet of iron was dipped in molten tin. If one side of the sheet had to be tinned, it was cleaned, warmed up and rubbed with tin. This method is no longer in use, having been replaced by the electrolytic bath.

Every tin can ends up in a rubbish heap sooner or later, but the tin it contains (about half a gram) is not lost, it is salvaged for recycling. To separate tin from tin plate is no problem: it easily dissolves in alkalis from where it is extracted by electricity. Other ways are practiced too. Since it readily reacts with chlorine, it is enough to pass a jet of dry chlorine over an old can for volatile stannous chloride to form, from which it is very easy to extract tin.

Tin is a comparatively low-melting metal. Recall Hans Christian Andersen's tin soldier which melted instantaneously when the wicked boy threw it into fire. The low

melting point of tin makes it the chief soldering component.

It is noteworthy that an alloy of tin (16 per cent) with bismuth (52 per cent) and lead (32 per cent) melts even in boiling water: the melting point of this alloy is only 95°C, while each of its components has a higher melting point: tin melts at 232°, bismuth at 271° and lead at 327°C. Alloys with gallium and indium have even lower melting points. One alloy, for example, melts at 10.6°C. Such alloys are used for electric fuses.

Tin is also added to various bronzes, type metals and babbitts (alloys characterized by high wear resistance and used for bearings).

The chemical compounds of tin are widely applied in technology. Stannous and stannic chlorides act as a mordant in the dyeing of cotton and silk. Natural silk is very light and is not easily dyed. But a treatment with these solutions causes stannic hydroxide to become deposited on the silk fibres (sometimes in quantities twice as heavy as the fabric itself) enabling them to retain the dye.

To give porcelain and glass a red tint, the purple of Cassius is used which forms when stannous chloride is added to a solution of chloride of gold. Stannic sul-

phide—mosaic gold—is used as a gold paint.

During military operations stannic chloride is to produce smoke screens: it readily reacts with water giving out a dense smoke of stannic oxide.

It is hard to say when man's acquaintance with tin began. It had been used as an alloy with copper (bronze) since before the dawn of history. Bronze weapons were much harder than copper ones. Evidently this explains the Latin "stannum" for tin derived from the Sanscrit "stan"—hard. However, unalloyed tin is a soft metal and there is nothing to justify this name. History has legitimized this paradox and metallurgists easily work pliant tin unsuspecting that they deal with a "hard" material.

Objects made of bronze were found in burial mounds dating back almost 60 centuries. Discussing the subject of mirrors, Pliny the Elder asserted that the "best mirrors known to our forefathers were made in Brundisium from a mixture of copper and tin".

It cannot be ascertained conclusively when human society began to use unalloyed tin. A tin ring and a vessel found in an Egyptian tomb of the 18th dynasty (between 1580 and 1530 B.C.) are believed to be the earliest articles made from tin.

In his *Iliad* Homer describes God of fire and metal Hephaestus forging and engraving a shield for Achilles:

*Also he set therein a vinyard teeming
plentifully
With clusters, wrought fair in gold:
Black were the grapes,
But the vines hung throughout on silver
poles;
And around them he ran a ditch cyanus,
And around that a fence of tin.*

When he was through with the shield,
the lame God set to work on the rest of

Achilles' armour:

*Now when he had wrought the shield
great and strong,
Then wrought he him a corselet
brighter than a flame of fire,
And he wrought him a massive helmet
to fit his brows,
Goodly graven, and set thereon a crest
of gold,
And he wrought him greaves of pliant
tin.*

In an old Inca fortress in Peru archaeologists found pure tin which had been apparently intended for the making of bronze: the inhabitants of this fortress were famous as expert metallurgists and bronzesmiths. Apparently the Incas had no other use for pure tin: among the objects found there was not a single one made from pure tin.

The Spanish conqueror Fernando Cortez, who was among those running over Mexico in the 16th century wrote: "A few small pieces of tin were found in the possession of the natives of Taxco province in the form of very thin coins; I continued my search and discovered that they were used as money in this province and in others..."

In 1925 archaeologists working on the site of a castle built in the 3rd century B.C. in England found smelting pits and in them tin-containing slags. That meant that tin production was developed in Britain already 2000 years ago. Tin production in some parts of Britain was also mentioned by Julius Caesar in his book *De Bello Gallico*.

In 1971 posthumous rehabilitation was granted to 94 British coiners who had been sentenced ... 847 years ago. It happened in 1124 when King Henry I was told that silver coins contained too much tin. The court session was speedy and the sentence harsh: the royal executioners chopped off the criminals' right arms there and then.

Now, eight centuries later, an Oxford scientist carefully X-rayed the wretched coins and drew the conclusion that "the coins contain very little tin" and that "the King was wrong".

Since time immemorial cassiterite or tinstone has been the main source of tin. The biggest tinstone deposits are found in the Malayan Archipelago. In the Soviet Union it occurs in the Far East, the Trans-Baikal area and in Kazakhstan. The museum of the Dalolovo Complex in Ussuriysk has one of the rarest specimens of a tinstone concretion in its collection: it is only 30 by 20 cm and 8 cm thick but weighs almost 50 kilograms.

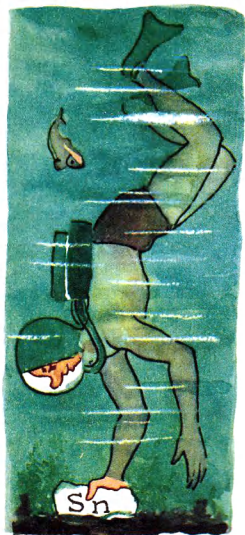
A portable gamma-resonance tin detector built several years ago enables geologists to determine the tin content of an ore within minutes. The special advantage of the device is that it reacts to cassiterite, while completely "ignoring" stannite for which industry has practically no use.

A major scientific breakthrough was marked recently when Soviet scientists proved that the presence of fluorine in a geological region could be a manifestation of the presence of tin. Their discovery was based on numerous analyses and experiments recreating, as it were, the picture of ore formation that took place millions of years ago. In those prehistoric times, it was found, tin existed in the form of a complex substance in which fluorine was inevitably present. Gradually tin and its compounds formed a sediment (future ore deposits) while fluorine, its former companion, remained in the vicinity for ever. This discovery will help not only to determine the likely regions of tin occurrences but also to prognosticate its reserves.

Geologists are looking for cassiterite both under ground and under water. So far they have discovered alluvial tinstone

deposits on the bottom of the Sea of Japan in Tikhango bay, and in the coastal waters of the Arctic Ocean—in the vicinity of Vankina Guba, Cape Svyatoi Nos and other areas. Divers are of great help to geologists nowadays, while the geologists themselves have added diving suits to their standard equipment—not much to do without one, say, on Svyatoi Nos.

The short supply of tin is the reason why scientists and engineers are constantly searching for some replacement, although tin itself has found increasingly wider application. Not long ago the American Ford Motor Co. built a factory for the continuous production of window-glass sheet, 2.5 metres wide. Molten glass is



poured into a 53 m-long bath where it spreads over a layer of liquid tin. Since the melt has an ideally smooth surface, the glass cooling and solidifying on it also becomes perfectly smooth and does not need polishing.

A new type of glass—in fact a trap for the sun—has been developed in the Soviet Union. It is different from ordinary glass in that it is covered by an extremely thin layer of stannic oxide. It is invisible and while easily letting the sun-rays through, it is vigilant against letting the warmth out. This glass is a godsend to vegetable growers: a hothouse which has been warmed up during the daytime will retain almost the same temperature over the night, whereas ordinary glass would have let all the calories out by morning. Plants are doing fine in the new hothouses even when it is 10°C below zero in the open air. Tin-filmed glass will be good in various sun-heaters and other installations transforming light energy into heat.

We wind up our chapter about tin with a happy-end story, almost a detective, in which tin played a crucial role.

The Second World War was drawing to an end. Realizing that the future was quite bleak for them, the rulers of the “independent” Slovak State knocked together by Hitler in 1939 on the territory of what today is Czechoslovakia, were determined

to fortify themselves against it by getting hold of the gold fund that belonged to all people of Slovakia. A group of patriotic bank workers in key offices resolved to frustrate the plan. Some of the gold was secretly transferred to a Swiss bank and frozen there up to the end of the war in the name of the Czechoslovak Republic, while the rest of the gold remained in the vaults of the Bratislava Bank.

One of the leaders of the puppet government secretly informed the German Ambassador in Bratislava about the valuables kept in the armoured vaults and asked him for a military detachment for the “bank operation” to remove the gold. True an SS general had to be accepted as a third companion but that guaranteed the success of the whole undertaking.

The SS men surrounded the bank building and an officer ordered the employees at gun point to surrender the gold. A few minutes later the cases with gold were taken from the vaults into the SS trucks. The robbers were rubbing their hands pleased with themselves, never suspecting that the gold ingots in the cases had been prepared by the director of the mint from ... tin. Meanwhile, the bank employees checked the seals on the secret caches where real gold had been hidden and waited impatiently for their country's liberation from the German troops.

BORN "IN TORMENT"



The torments of Tantalus.—Confusing similarity.—Heinrich Rose clarifies the situation.—Hand in hand.—100 years old.—Premonition comes true.—“Have you got a recommendation?”—No bigger than a match-head.—Growing interest.—Aqua regia is powerless.—“Are skulls mended here?”—Tantalum nerves.—A correct diagnosis.—On a humane mission.—An important customer.—At monstrous temperatures.—Close contacts.—Employed on a “hot” job.—In solidarity with Tantalus.—Envious constancy.—In jewellers’ hands.—Outlays are recouped.

One day the Phrygian King Tantalus, the favourite son of Zeus, who wanted to impress the gods he had invited to his feast, treated them to the flesh of his own son Pelops. Incensed by his cruelty the gods doomed Tantalus to perpetual torment by thirst, hunger and fear.

Since then Tantalus has been standing in the lower world, up to his chin in clear water, branches overgrown with ripe fruit bending low to him. When Tantalus opens his mouth to quench his thirst the water flows away from his lips and when he raises his hand to get the fruit the wind blows the branch high but the wretched sinner is too weak to reach it. And above, an overhanging rock threatens to crush him down any minute.



That is how the Greek myth tells about the "torments of Tantalus".

The Swedish chemist Andres Ekeberg must have remembered about it when time after time he repeated his futile attempt to dissolve in acids the oxide of the new element he discovered in 1802. The scientist seemed to be so close to success, but still he failed to extract the new metal. Finally he gave up and remembering about his tortuous experience, evidently, he decided to give the new element the name "tantalum".

After a while it became clear that tantalum had a twin, although born a year before. It was columbium discovered by the British chemist Charles Hatchett in 1801. The two elements were so strikingly similar that many chemists were misled and after a long argument arrived at the conclusion that the two were one and the same element, tantalum.

The confusion lasted for more than forty years. It was only in 1844 that the German chemist Heinrich Rose clarified the situation and proved that columbium had a right to a place in the sun as much as tantalum. Since the two elements were obviously related to each other in many respects, Rose named columbium "niobium" (Niobe was Tantalus' daughter).

Since then tantalum and niobium have lived side by side and their fate has not all been smooth sailing.

The industrial world showed not the slightest interest in tantalum for many decades. And as a matter of fact there was no tantalum as such in existence: it was already 100 years after its discovery that scientists managed to extract it in pure compact form. That happened in 1903 and the same year it got its first job. Learning that it was a very high-melting metal scientists decided to try it for the filaments in electric lamps. At that time tantalum had no other offers and it "agreed" although it "had a feeling" that this was not its true calling.

Indeed the harsh competition laws governing the world of metals soon deprived tantalum of its job. It was replaced by tungsten, a metal which had even a higher melting point, hence was luckier.

There came years of forced idleness. At the "labour exchange" only those metals were considered "eligible" that were either well-known or were able to produce excellent recommendations from physicists, chemists and other scientists. Tantalum had few acquaintances in the world of science and technology and was compelled to "sit doing nothing". But finally, in 1922 it had its lucky break: it was successfully tested in rectifiers and a year later, in electron tubes. It was then that the development of industrial processes to produce this metal began.

Interestingly enough, the first industrial tantalum bar (the semifinished product to be further processed) obtained in 1922 was the size of a match-head. The bars that have been produced lately are sometimes 1 000 times as big.

The content of tantalum in the earth's crust is only 0.0002 per cent, but more than 130 of its minerals are found in nature (as a rule tantalum in them is inseparable from niobium). The principal raw material for the production of tantalum are tantalite and columbite, deposits of which occur in Africa and South America.

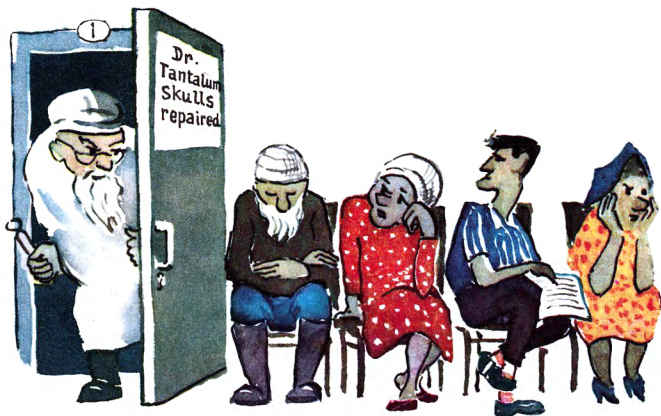
While before the Second World War the annual production of tantalum-niobium ores was only 600-900 tons, in 1944 it had grown several times over. Between 1940 and 1944 it went up 12 times in the United States alone. The increased interest in this metal was due to the fact that the many of its valuable properties revealed by then could not have left people working in various branches of technology indifferent.

Tantalum is a light grey metal with a bluish tinge. Its melting point (3000°C) is second only to tungsten and rhenium. Its high strength and hardness are combined



with high ductility. Pure tantalum readily yields to many kinds of mechanical processing, such as stamping and rolling (tantalum sheets can be as thin as 0.04 millimetre) and drawing into wire.

But the most important property of tantalum is its outstanding chemical resistance in which it is inferior only to the noble metals and not even in all cases. It will not dissolve even in such notorious chemical "aggressors" as aqua regia and concentrated nitric acid. At 200°C submerged in 70 per cent nitric acid tantalum does not corrode at all; no corrosion is observed in sulphuric acid at 150°C either, and at 200°C corrosion affects the metal up to no more than 0.006 millimetre a year. This makes it a very valuable structural material for the chemical industry. Tantalum equipment is used in the production of many acids, including hydrochloric, sulphuric, nitric, phosphorus and acetic acids, as well as hydrogen peroxide, bromine and chlorine. At one chemical plant working with hydrogen chloride gas stainless steel components broke down only after two months in operation. But when tantalum replaced stainless steel even the thinnest parts (0.3-0.5 millimetre) had their life increased up to 20 years. Hydrofluoric acid is the



only substance to which even tantalum gives in.

Tantalum cathodes are used for the electrolytic extraction of gold and silver. Their advantage is that whereas aqua regia dissolves the gold and silver deposition it can do them no harm.

Tantalum's "biological compatibility", that is, ability to grow into living tissues without causing any irritation, is unique. Hence, its extensive application in medicine, mostly in reparative surgery. Tantalum plates, for example, are used to seal skull fractures. Medical literature has recorded a case where a tantalum plate was used to make an artificial ear. The skin transplanted from the thigh onto it had grown to the metal so fast that it was hardly possible to say which one was the new ear. Tantalum yarn is used to build up damaged muscular tissues. Surgeons also use this metal for postoperative reinforcement of the abdominal walls. Tantalum clamps, not unlike those used to

bind notebooks, securely connect blood vessels. Tantalum gauze is inserted in artificial eyes. The thinnest tantalum fibres replace tendons and even nerve fibres. Therefore, while the expression "steel nerves" is used figuratively, "tantalum nerves" can be used in the direct sense.

Swiss physicians believe that tantalum should be an efficient means of diagnosis when the bronchi and lungs are X-rayed. When breathed in, fine tantalum powder which is absolutely harmless for the human organism gets into the smallest divisions of the bronchi from where it will be removed by the cilia of healthy cells. But sick cells cannot clear themselves from the dust and so retain it marking off, as it were, the affected area on the X-ray photograph and ensuring a correct diagnosis.

Perhaps medicine is not the most important job of tantalum, but it is certainly its most noble one. There is really something symbolic about the fact that a metal bearing the name of a mythical

martyr should fulfil the humane mission of relieving human suffering.

A mere five per cent of the world tantalum production goes into medicine, while 20 per cent is consumed by the chemical industry. The bulk of the production, however, (more than 45 per cent) is applied in metallurgy. Of late years tantalum has been increasingly used as an alloying element in special steels—super-strong, corrosion-resistant and refractory. The effect of tantalum on steel is similar to that of niobium. An addition of these metals to corrosion-resistant chromium steels enhances their strength and reduces brittleness after hardening and annealing.

Tantalum is very important in the smelting of heat-resistant alloys the need for which is constantly growing in rocketry and space engineering. An alloy of 90 per cent of tantalum with 10 per cent of tungsten possesses remarkable characteristics: sheets made from this alloy can be used at temperatures up to $2\,500^{\circ}\text{C}$, while more massive parts can withstand monstrous temperatures of over $3\,300^{\circ}\text{C}$. Foreign specialists believe that this alloy is perfectly reliable in jets, exhaust pipes, component parts of gas control and regulation systems, leading edges and other vital assemblies of spaceships. In cases where rocket nozzles are cooled by liquid metals (lithium or sodium) capable of causing corrosion it is absolutely impossible to do without an alloy of tantalum with tungsten.

The heat resistance of the tantalum-tungsten component parts becomes staggering if they are coated with tantalum carbide (melting point $4\,000^{\circ}\text{C}$). During tests the coated nozzles withstood temperatures at which uncoated ones corroded fast and broke.

The hardness of tantalum carbide is close to that of diamonds owing to which it is widely used in the production of hard alloys. In high-speed cutting, the cutting



tool heats up to such an extent that filings become fused with it, causing its edge to crumble and break. The cutting tool made from a hard alloy is not threatened by crumbling and its service life is very long.

Many of tantalum's jobs are intimately connected with electricity. Electrical engineering and electron device industry consume something like 25 per cent of the world production of tantalum. Tantalum rectifiers are used in railway signalling systems, telephone commutators, and in fire-alarm signalling systems. Miniature tantalum capacitors are used in radio transmitters, radar and other electronic circuits.

Various components of electron devices are also made from tantalum. Just as niobium it is an excellent getter, i.e. gas absorber: at 800°C it can absorb 740 volumes of it. When absorbing the gases which remain in the electron tubes after evacuation the getters ensure a high degree of rarefaction. Tantalum is used for the "hot" components of tubes: plates, grids, indirectly heated cathodes, etc. It is especially important in tubes that operate at high temperatures and voltages when they have to retain precise characteristics

for a long time. In some vacuum tubes tantalum is used to sustain the pressure of gases at a definite level. Tantalum wire is found in cryotrons—the superconducting elements used in the computer industry.

Tantalum is also an excellent material for spark-gap tubes. As though in solidarity with its mythical namesake Tantalus, here it challenges Zeus the Thunderer by arresting lightning bolts that he sends to earth in his fury.

In artificial silk production the dies for drawing the fibres have tiny openings, not bigger than a few hundredths of a millimetre which get blocked up very often and have to be cleaned continually, so that their size remains constant. Naturally such dies require a strong, wear- and corrosion-resistant materials. Tantalum answers all these requirements.

Of late tantalum has had a trial also in jewelry where it effectively replaces platinum in many cases. This leads to impressive economy, since platinum is 15 times more expensive than tantalum. It owes its application in jewelry largely to

its property to become covered with a beautiful iridescent oxide film. So we have tantalum watches, bracelets and other ornaments.

The Bureau International des Poids et Mesures in France and the Bureau of Standards in the United States use tantalum instead of platinum to make sets of highly precise analytical weights. In fountain pen nibs tantalum points replace the extremely expensive iridium.

Although tantalum is not as expensive as, say, platinum or iridium, the price for it is high enough. This is largely to be explained by the costliness of the materials used in its production and by the complexity of its extraction processes. Suffice it to say that the production of one ton of tantalum concentrate requires the processing of up to 3000 tons of ore. But the expenses are repaid with interest.

Long past are the years when tantalum was a “young” element in search of a job. As you have seen, in our day this metal has plenty to do, but this is not all. A spectacular future is yet to come to it.

GIVING LIGHT



Is comment needed?—"Wolf's froth".—A druggist's discovery.—Mushet's self-hardening steel.—No turning back.—Peach-coloured.—Experiments at the Putilov Plant.—German engineers' success.—Driven by need.—A tasty morsel.—Never to be allowed.—The long silence.—The Princes Vladimirovich's "plot".—"The dynasty will go to hell".—Outside "aid".—In frost and heat.—Return of the "fugitives".—At the Sun's surface.—Thousands of millions of lightnings.—Minutes and ages.—Uran-1 in Montreal.—"Whiskers" are the coming thing.—Tungsten's "savings".

The names of many elements speak for themselves: hydrogen—"producing water"; carbon—"producing coal"; mendelevium, einsteinium, fermium, curium and kurchatovium—all honouring outstanding scientists; europium, americium, francium, germanium and californium speaking of the places where they were found. But the names of some elements require an explanation. One of them is tungsten or wolfram. Wolfram means "wolf's froth". What can this element of the VI group of the Periodic Table and the forest carnivore have in common?

It was a long time ago that metallurgists noticed that sometimes there was a sharp drop in the amount of tin smelted from ore. Our forefathers naturally were not indifferent to the technical and economic characteristics of smelting and they began to watch closely the ore which was taken in for smelting. Soon they noticed that trouble always started when the ore contained heavy stones of a brownish or yellowish-grey colour. The conclusion seemed obvious: the stone "devoured" tin like a wolf devours sheep. And the stone was called "wolf's froth". In some countries the same stone got a different name—tungsten or "heavy stone".



Tungsten was discovered by the outstanding Swedish chemist Karl Scheele who was a druggist by profession. He carried out numerous remarkable experiments in his small laboratory and discovered oxygen, chlorine, barium and manganese. In 1781, not long before his death, Scheele, by then a member of the Stockholm Academy of Sciences, established that the mineral tungsten (subsequently called scheelite) was the salt of an unknown acid. Two years later the Spanish chemists brothers Delhujar working under Scheele, were able to extract a new element—wolfram—from this mineral which was destined to create a revolution in industry. But that happened 100 years later.

In 1864 the Englishman Robert Mushet was the first to add tungsten (about 5 per cent) as an alloying element to steel. His steel which went down in the history of metallurgy as "Mushet's self-hardening steel" could withstand red heat while not only retaining but adding to its hardness. Cutters manufactured from this steel made it possible to increase the speed of metal cutting by 50 per cent (7.5 metres a minute instead of 5).

Something like 40 years later high-speed steel already containing 8 per cent of tungsten was developed. Now the speed of cutting was 18 metres a minute. A few years passed by and the speed grew to 35 metres. Thus in some 50 years tungsten had been able to build up the efficiency of metal-cutting tools 7 times!

Was it possible to increase the speed some more? Steel was powerless at that point even with the addition of tungsten. Did it mean that the limit had been reached and that it was impossible to cut metal faster?

Again the answer was provided by tungsten. It had not exhausted all its abilities, it seemed, and was not going to turn back in face of high temperatures in the battle for high-speed machining. In

1907 a new alloy was developed on the basis of tungsten, chromium and cobalt—stellite—which marked the beginning in the development of modern hard alloys, ensuring even a greater speed of cutting and bringing it to today's fantastic 2000 metres a minute.

The amazing distance from five to 2000 metres covered by metal cutting has been made possible by ever new tungsten compounds.

Modern superhard alloys are a combination of tungsten carbides and carbides of some other elements (titanium, niobium and tantalum) produced by sintering, with the grains in the alloys cemented, as it were, by cobalt. Such materials called cermets, do not lose in hardness even at 1000°C and therefore allow for colossal speeds of machining. The hardness of one tungsten-carbide composition is such that if an attempt to scratch it with a file is made, the file and not the material will be scratched.

However, machining was not the only branch through which tungsten made its way into technology. It was noticed in the middle of the last century that fabrics impregnated with the sodium tungstate acquired refractoriness. At about the same time tungsten-containing yellow, blue,

white, violet and green paints were developed. They were used in painting ceramics and porcelain making. Surviving to this day are porcelains manufactured in China as far back as the 17th century and famous for their unique "peach colour". A chemical analysis carried out in our day revealed that the porcelain owed its delicate colour to tungsten.

In 1860 an iron-base alloy with tungsten—ferrotungsten—was produced by heating iron with tungstic acid. The hardness of this alloy impressed chemists and metallurgists so much that industrial ferrotungsten production was developed very soon.

The first attempts to introduce tungsten in gun steel date to 1882. Professor V. N. Lipin smelted tungsten steel at St. Petersburg Putilov Plant in 1896. Even a small addition of tungsten to steel greatly increased the resistance of gun barrels to corrosion under the effect of gunpowder fumes. German engineers were ahead of others in realizing the meaning of such steel. During the First World War the light German guns successfully withstood up to 15000 blasts while the Russian and French ones were ruined only after 6 to 8 thousand blasts.

It was only natural that the production



of tungsten ore increased rapidly during that period: from a total world annual output of 200-300 tons in the 1890s to 8000 tons in 1910 and 35000 tons in 1918.

But still tungsten was in short supply. Germany had almost no sources of its own and experienced an especially acute need in it. True, during the period of war preparations the far-sighted Germans stored up some amount of tungsten ore, but soon it was exhausted and the war industry was clamouring for more.

German metallurgists were racking their brains to find a way out, and, necessity being the mother of invention, they soon remembered about the "wolf's foam". It was known that when the "foam" "devoured" ore, it carried tin to the slag heaps and that whole mountains of tin slags had accumulated throughout Germany, where tin production dated to the beginning of the 17th century. In a short while metallurgists began to extract tungsten from them. It goes without saying that slags were not enough to satisfy tungsten hunger, but still it was "a bite to eat".

Meanwhile tsarist Russia produced miserly amounts of this valuable metal even during the general rise of the tungsten industry. In 1915 the Izhora works (near St. Petersburg) received a consignment of only 1.4 tons of tungsten ore from a mine in Transbaikalia and in 1916 the Motovilikh works (north-west of the Urals) got 8.7 tons. The production of ferrotungsten during that period amounted to only 60 pounds at one of the Petrograd (former St. Petersburg) works.

The deposit in Transbaikalia was like a tasty morsel to many foreign firms, particularly Swedish and Japanese ones. In the summer of 1916 Japanese geologists surveyed the region of Mount Antan. The results of their expedition must have been promising, since the directors of the firm which employed them made repeated attempts to lay their hands on the deposit but were denied a lease.

The better known Bukukino and Oldandu deposits were in those years jointly leased by the industrialist Tolmachev and mining engineer Zix. At one point the two businessmen decided it would be profitable for them to re-lease the deposit to the Swedish firm Mortimer and Bogaju whose representatives showed the liveliest interest in it after they had inspected it. Tolmachev was preparing to pocket 30000 roubles as an advance payment on the agreement with the firm, but he was not to have it: suspecting that Tolmachev had deliberately belittled the estimated reserves of tungsten, the Geological Committee suggested that in view of wartime difficulties the Tolmachev mines should be requisitioned and transferred to the jurisdiction of the royal cabinet. Soon the Committee's proposal was given royal approval.

This is what Academician Alexander Fersman wrote about that period: "Before the October Revolution the Natural Productive Forces Commission of the Academy of Sciences was prevented from doing all that it could. Russian science was in a difficult situation and scientists' initiative often encountered numerous barriers. For two years the Academy had been unable to obtain even the smallest credits to go about solving such an exceedingly important problem as the development of tungsten deposits."

But it must be said that finances were not the only nor the worst problem scientists were confronted with. An episode recalled by Academician Alexey Krylov, an outstanding scientist and ship designer, in one of his books is highly noteworthy in this respect. In January 1917, that is during the last weeks of Nicholas II's reign, the Natural Productive Forces Commission of the Academy was discussing the question of tungsten production in which Russian industry was greatly interested. An influential tsarist official reported on the situation and said that there were tungsten deposits in Turkestan



and that 500 roubles were needed to fit out an expedition to those parts. A long silence followed his words. Almost all those present knew that there were lands rich in tungsten also in the Altai, but no one was bold enough to mention it because that land—one of the richest areas in Russia—belonged to the Great Princes Vladimirovich, the tsar's close relatives, and it was criminal even to think of prospecting there.

The long pause was broken by Academician Krylov: "As far as the Turkestan mines are concerned, everything is very simple. Here are 500 roubles." He drew out a banknote bearing Peter I's picture and gave it to Academician Fersman, who chaired the sitting. "But," he continued, "the question of Altai is much more difficult. The speaker has failed to mention that the mines there are on the land belonging to the Great Princes Vladimirovich. Tungsten means high-speed steel, or more than double the rate of shrapnel production. If requisitioning or exploitation of it is in place anywhere, it is there: without shrapnel the war will be lost and that will mean that not only the

Vladimirovich but the whole dynasty will go to hell."

The bold scientist's words were prophetic: a month later the Romanov dynasty was overthrown.

"Aid" coming from foreign specialists was another brake on the development of the national tungsten industry. In 1931, while sorting out old mineralogical collections, researchers at Moscow University discovered specimens of sheelite found in the then unknown deposit in Mogoltau Mountains, Tajikistan. It was established that those specimens had been found as early as 1912 and sent to Moscow for analysis. But leading German geologists who had been asked to give their opinion pronounced the deposit economically unprofitable and the tsarist government decided not to develop it. But the commission sent to Tajikistan after the discovery at Moscow University soon proved that the Mogoltau deposit was one of the richest in the country.

At about the same time Academician S. S. Smirnov, a leading Soviet geologist, launched, together with his pupils, an extensive search for tungsten throughout

the country. The geologists covered thousands of kilometres in heat and frost, on foot and on dog and reindeer sledges. Wherever the daring prospectors went—Transbaikalia, Yakutia, or the Sea of Okhotsk—new mines emerged and new works were built. That was the beginning of the Soviet tungsten industry.

Today about 80 per cent of tungsten extracted in the world is consumed by the high-grade steel metallurgy, nearly 15 per cent goes into the production of hard steels and the remaining 5 per cent is used as the pure metal owing to its amazing properties.

In order to melt tungsten it has to be heated to a temperature at which most metals evaporate, that is, almost to 3400°C . Tungsten could survive in liquid state even near the Sun itself: its boiling point is over 5500°C . Its high melting point makes it widely applicable in electrical engineering, one of the key modern industries.

Since the tungsten filament ousted the carbon, osmium and tantalum ones in electric lamps in 1906, tiny tungsten lightnings light up our homes every evening. Several thousand million electric

lamps are produced in the world every year. Is it a lot? Judge for yourself: since the beginning of chronology mankind has lived a little over one thousand million minutes (at 10:40 a.m. on April 29, 1902 the second thousand million minutes of chronology began).

Scientists and engineers are constantly working to improve the electric lamp and make its life longer. Just like a burning candle melts, so tungsten begins to evaporate from the surface of the incandescent filament when the lamp is turned on. In order to reduce evaporation and prolong the lamp's life various inert gases are pumped in it under pressure. It was suggested recently that iodine vapour should be used for this purpose: this substance "captures" the evaporating molecules of tungsten, combines with them chemically and, settling on the filaments, returns the "fugitive" molecules and makes the lamp serviceable for a much longer period.

The assortment of electric lamps is extremely wide: from miniature "beads" used in medicine to powerful searchlights.

At the World's Fair in Montreal the Soviet Pavilion exhibited a new radiation-heater, *Uran-1*. One of its main components was a water-and-air-cooled lamp. A bulb of a comparatively small size made of refractory quartz and filled with the inert gas xenon has two tungsten electrodes. When the lamp is switched on gas plasma emerges between the electrodes. Its temperature is about 8000°C . A special mirror, compared to which standard ones are like dull tinplate, directs the infrared rays of the artificial "sun" (the lamp produces the solar spectrum) to the optical system which focusses into a beam having a little more than one centimetre in diameter. The temperature of the beam at the focus reaches 3000°C . *Uran-1* can function under such "hot" operational conditions for hundreds of hours non-stop.

Widely applied in technology are



so-called cathode rays—an electron beam emitted by a metallic cathode surface into vacuum (electron emission). It has been practically demonstrated that tungsten is one of the best materials for such cathodes.

Tungsten is not only the highest-melting metal, but in pure form it also possesses colossal tensile strength—40 tons per square centimetre, which is much greater than that of the best steel. And it retains this characteristic even at 800°C!

The high strength of metallic tungsten is combined with good ductility: it can be drawn out into an extremely thin wire 100 kilometres of which weigh only 250 grams!

Apart from being extensively used in electric lamps, tungsten wire was recently suggested as a cutting tool for brittle materials. An ultrasonic generator transmits waves to the tungsten filament which slowly cuts into the material being processed. The new cutter easily handles such materials as quartz, ruby, pyroceramic, glass and ceramics, cutting them with the utmost precision into parts or leaving grooves and slits of any shape and any size.

Strong as the tungsten filament is, it is far inferior to the strength of the tungsten “whiskers”—minute crystals that are hundreds of times thinner than human hair. Soviet scientists have developed “whiskers” two-millionths of a centimetre in diameter. Their strength is 230 tons per square centimetre, which is almost the absolute ceiling of strength—the theoretical limit estimated by science for terrestrial bodies. But so far this miraculous metal has not left the laboratory.

Pure tungsten used in technology is produced by hydrogen reduction of tungsten trioxide. The finest powder thus obtained is pressed and sintered at a temperature of up to 3000°C. This metal is used in incandescent filaments, components of electron and X-ray tubes and switch contacts.

Scientists have developed a process of

growing single crystals of tungsten, molybdenum, and other high-melting metals by arc plasma. This process was used in the Institute of Metallurgy of the USSR Academy of Sciences to produce a tungsten single crystal weighing 10 kilograms. Owing to its high purity this metal is characterized by extraordinary mechanical properties: at very low temperatures it almost fully retains its ductility, while at high temperatures the same can be said about its strength. Single crystals are used in many electron devices.

An interesting experiment in which tungsten played an active part was staged during the joint flight of Soviet and American spacemen under the Soyuz-Apollo programme. In terrestrial conditions it is difficult and often simply impossible to alloy metals of substantially differing density: during smelting and crystallization the particles of the heavier metal tend to settle in the lower layers of the ingot while those of the lighter metal arrange themselves in the upper layers. Naturally it is impossible to make use of such a heterogeneous alloy. But smelting in space is an entirely different thing. Under the conditions of weightlessness all elements are equal—both light and heavy metals—and an alloy smelted in space is expected to be uniform both in composition and structure. The purpose of the experiment was to smelt, using the so-called “universal furnace”, an alloy of the light and low-melting aluminium with the heavy-weight tungsten, characterized moreover, by a record-breaking high melting point.

That experiment was only the beginning of space technology. “Some time will pass,” says Valery Kubasov, one of the participants of the historical flight, “and we will be able jointly to create real factories in space. Their goal will be an entirely new metallurgy: production of alloys and materials that are impossible to produce in terrestrial conditions.”

In 1929 an interesting calculation was made in the United States concerning the economic effect of the introduction of tungsten into technology. The development of the incandescent filament saved 400 000 dollars; the manufacture of one automobile by means of tools made from tungsten steel was 40 dollars cheaper than that manufactured by means of carbon steel tools; the total economy in the motor

industry which was due to the introduction of tungsten was even then 500-600 million dollars a year.

For ages have metals faithfully served mankind, helping it to create the unique world of technology. Tungsten which has played one of the leading roles in this process, is today ahead of many other metals in reaching the horizons of the future.

BEHIND THREE LOCKS



The Spanish conquistadors' find.—The King's order.—Close relations.—The first in Russia.—“Diamond” steel.—A discovery is doubted.—The Finance Minister makes a mistake.—Collecting platinum coins.—A treasure in rubbish.—The Demidov Prize winner.—“One-gram output”.—Warm reception.—Sparks that are not extinguished by wind.—Through platinum gauze.—How is the “hunger” to be satisfied?—In a grim year.—Transparent mirrors.—Montezuma's gift.—Platinum thermometers.—Three keys.—On the basis of platinum.—“For all times, for all people”.—Orange light.—Platinum diagnoses.—Blocking all pain.—An honourable duty.

The ancient states of the Aztecs and Incas were among those whom the Spaniards ruthlessly plundered in the 16th and 17th centuries. Tons of gold, silver and emeralds filled the holes of the galleons constantly cruising between Spain and South America.

A Spanish detachment moving along the river Platino del Pinto (Colombia) one day discovered gold and grains of an unknown heavy silvery metal on its banks. It had an extremely high melting point which made it absolutely useless to them and only interfered with gold refining. They contemptuously called it "platino" which meant poor-quality silver. Substantial amounts of platinum were nevertheless shipped to Spain where it was sold much cheaper than silver. Some time had passed and Spanish jewellers discovered that platinum was easily melted with gold and those that were dishonest began to mix it in with gold when making jewelry, but even more so, false coins. On learning

about the swindling, the King had the bright idea of issuing a decree which banned shipments of the useless metal to Spain and ordered the elimination of all its stocks so that the swindlers would no longer be able to cheat honest people out of their money. All platinum in Spain was collected and dumped into the sea in the presence of witnesses. That sad episode concluded the first chapter in the history of platinum.

Years had passed before this metal was mentioned again. The first to do so were scientists. An important contribution to the study of platinum was made at the end of the 18th century by the noted Russian chemist Apolos Apolosovich Musin-Pushkin, Vice-President of the Mining Collegium in St. Petersburg and honorary member of many foreign Academies of Sciences.

The study of platinum resulted in the discovery of several metals accompanying it naturally, which were given the general name platinum metals: palladium and rhodium were discovered in 1803, osmium and iridium in 1804 and ruthenium, the last element in this group, forty years later. Subsequently it was found that ruthenium was the rarest of platinum metals which was probably why it had not been discovered earlier.

Further platinum study was greatly promoted by the discovery in 1819 of considerable alluvial deposits of this metal near Ekaterinburg (today Sverdlovsk) in the Urals. Five years later Russia's first platinum mine was commissioned there, on the bank of the small Baranchi river.

At about the same time platinum began to be used as an additive to steel. The *Mining Journal* wrote that "six pounds of steel were melted with eight *zolotniks* (a 96th part of the Russian pound) of refined platinum in a refractory earthen pot sealed so as to protect the metal from the air. The melt was poured into an iron mould and quickly cooled in cold water. When the bar was broken the steel was found to



be of a uniform structure and so fine-grained that it was impossible to discern its granular composition with the unaided eye. When it was sharpened and hardened without annealing it cut glass like a diamond and chopped iron without becoming blunt. In general platinum steel is much harder than any hitherto known metals and withstands the heaviest impacts without breaking." For its uncommon hardness it was called "diamond steel" (platinum steel had been regarded as the hardest for a long time until it was surpassed by the less expensive but even more "capable" tungsten).

In 1828 Professor G. V. Osann of the Derpt (Tartu) University treated some native platinum ores from the Urals with aqua regia and arrived at the conclusion that they contained three elements unknown to science which, judging by their chemical properties, belonged to the platinum metals group. He gave them the names poluranium, polynomium and ruthenium. The discovery was called into question by the Swedish chemist Berzelius. Osann decided to repeat his experiments, but the new results did not confirm his initial proposition and the scientist had to renounce it.

By that time platinum had already attracted the interest of not only scientists but also of the tsar's financiers. In 1828 Count Ye. F. Kankrin instructed the Mint to start the coining of platinum pieces of 3, 6 and 12 roubles' denomination.

But the instruction presented a tough problem: not one of the then existing furnaces could heat platinum to the required 1769°C.

The problem was taken up by P. G. Sobolevsky, a St. Petersburg engineer and founder of the Combined Laboratory of the Mining and Salt Works Department, the Mining Cadet Corps and the Chief Mining Pharmacy. The problem was uncommonly difficult for those times and an uncommon approach to it had to

be found. He filled a coin mold with sponge platinum (obtained when platinum ores are treated chemically), pressed it and then heated it to about 1000°C. Contrary to all expectations, the metal "let up": without having been melted sponge platinum was transformed into coins which in their external appearance could not be told from cast coins. Thus, for the first time in the history of world metallurgy a unique process retaining its significance to this day was developed by a Russian engineer. It was only three years later that an analogous process for the manufacture of platinum items, subsequently termed powder metallurgy, was rediscovered by the English chemist W. H. Wollaston.

In recognition of Sobolevsky's great services the Minister of Finance proposed that he should be paid a yearly sum of 2 500 roubles in addition to his salary "as long as he stays in his job". The tsar approved the Minister's proposal.

Thanks to Sobolevsky's work the Mint was soon turning out platinum money at a high rate. Within a short period of time 1 400 000 platinum coins were minted, consuming nearly 900 pounds of platinum (about 15 tons). Since this metal was becoming more expensive every day, the government realized it had made a mistake: the price of platinum coins was also rising and their real value was becoming considerably greater than their nominal price, and very soon they had completely disappeared from circulation. That process was boosted, on the one hand, by the Finance Ministry's measures intended to restore the treasury's platinum and on the other, by private individuals who preferred to deal in other money and keep platinum coins for themselves. Today these coins are a great rarity and can be seen only in very select numismatic collections.

The platinum coins had done an unexpected service to science. Substantial remains of platinum ores—the waste



product of coinage—had accumulated in the laboratory of the St. Petersburg Mint. In 1841 Professor Karl Karlovich Klaus of Kazan University, who was greatly interested in the work of Osann, asked the Mint to send him two pounds of the wastes. In them the scientist was greatly surprised to find up to 10 per cent of platinum and small quantities of osmium, iridium, palladium and rhodium.

The wastes which had interested no one until then had suddenly become a treasure. Klaus immediately informed the Mining Department of his results. In a little while he was received by Count Kankrin in St. Petersburg, that same count who had sanctioned the minting of platinum money. The Count took the chemist's report very seriously and helped him to obtain the platinum "left-overs" for further research.

Klaus's perseverance brought him success: he was able to prove that among the other known elements the wastes contained a new metal, namely ruthenium, described by Osann in his time. His reasoning was so convincing that even Berzelius, who had again expressed his doubts concerning the discovery of a new element of platinum group, was finally compelled to admit his mistake. For his

discovery Klaus was awarded the full Demidov Prize—1000 roubles.

Meanwhile platinum production was growing rapidly in the Urals. It is noteworthy that in 1915 Russia turned out 95 per cent of the total world production of this metal (five per cent came from Colombia). Lately the world market has also been supplied by platinum from South Africa, Canada and the United States, but the Soviet Union continues to hold an important place in the platinum industry.

It is noteworthy that while the annual world gold production has long since topped the one-thousand-ton level, platinum production is still measured in tons. To illustrate: in 1960 all the capitalist countries produced a little more than 16 tons between them. In the words of the Soviet poet Mayakovsky, "a gram of product—a year of work". Indeed, to produce one gram of this metal it is sometimes required to process hundreds of cubic metres of ore. This is to be explained by the extremely small amount of platinum present in ore and by the fact that big deposits of it are yet to be discovered. And native platinum is a very rare occurrence. The biggest nugget ever found weighed less than 10 kilograms.

It was as early as the beginning of the last century that platinum was first used for a practical purpose. It happened when someone thought of manufacturing platinum retorts to store concentrated sulphuric acid. Owing to its incredible chemical resistance, the metal has been used in chemical laboratories (platinum crucibles, bowls, sieves, pipes, etc.) ever since. Large amounts of platinum are consumed by the construction of acid- and heat-resistant equipment for chemical plants.

Despite the fact that the platinum stirrer which is used to stir the molten glass mass at the famous Czechoslovak glass factories costs 750 000 kronen and the platinum crucible in which the stirring is made is

twice as expensive, it is worth this money: the equipment is considered to be most up-to-date and ensures the production of top-quality glass for the microscopes, binoculars and other optical instruments.

Platinum's other important role in chemistry is being a catalyst in many processes. A lighter recently invented in Hungary operates on the basis of, this quality of platinum. The lighter has neither the traditional serrated wheel nor flint and it is enough to remove the cap to start the flame going: the gas coming out of the lighter flares up from contact with air. But this reaction takes place only in the presence of the catalyst—the platinum ring bordering the opening through which the gas escapes. This lighter cannot be extinguished by the wind, moreover, the stronger the wind the faster the reaction and the higher the flame. The flame goes out the minute the cap is back in place on the ring.

As a catalyst platinum is indispensable in nitric acid production for the oxidation of ammonia. A mixture of ammonia and air is blown at a high rate through a very fine platinum gauze (which has up to 5000 meshes per sq centimetre), as the result of which oxides of nitrogen and water vapour are produced. Dissolving in water, these oxides yield nitric acid.

In Russia, platinum began to be used in the industrial production of nitric acid thanks to the work of I.I. Andreyev, pioneer of the national nitric acid industry, who had devoted special attention to the study of influence of various catalysts on the oxidation of ammonia.

That was during the First World War when the need for nitric acid was enormous: the production of every kilogram of explosives required more than two kilograms of nitric acid. By the end of 1916 the monthly amount of explosives needed by the Russian Army was something like 6400 tons. Chile was the only country that possessed the natural raw

material for the production of nitric acid. Hence, the acute nitric-acid "hunger" of all the belligerents and their feverish attempts to find ways of satisfying it.

It was then that I. I. Andreyev suggested ammonia contained in the coke oven wastes as the much-needed raw material. His preliminary experiments had convinced him that ammonia oxidized at a very fast rate in the presence of platinum. Andreyev designed the first nitric acid plant in the Donbass where most of the coke and chemical plants (hence large amounts of ammonia) were situated. It was commissioned in the summer of 1917, putting an end to the nitric-acid problem.

The great importance which had begun to be given to platinum by that time is illustrated by the fact that in 1918, a grim year for Russia, a special institute for platinum study was organized later to become affiliated to the Inorganic Chemistry Institute of the USSR Academy of Sciences. Major research into the chemistry and technology of the platinum group elements continues there to this day.

It is not only chemists who need platinum. Its ability to be sealed in with glass makes it indispensable in many glass-enclosed devices.

A very thin platinum layer deposition on glass makes a mirror possessing the amazing property of one-way transparency: it is nontransparent on the side where the source of light is situated and reflects objects like an ordinary mirror, but on the reverse side it is transparent like glass through which all the objects behind it are clearly visible. At one time platinum mirrors were very popular in the United States and were used as window glass in the lower storeys of buildings housing offices and institutions and in private apartments where they made curtains unnecessary.

It must be said that ancient Aztecs were the first to make platinum mirrors, although not on the basis of glass but wholly



metal ones—smooth and well-polished platinum sheets. It is still a mystery, how they managed that achievement, for it is a fact that platinum can be welded and forged only if it is white-hot, i. e. heated to a temperature clearly unattainable in those days. And yet it was managed: the great Aztec ruler Montezuma sent several such mirrors to the King of Spain. The monarch "repaid" him handsomely: in 1520 Montezuma was imprisoned and executed.

The ability of platinum sponge to absorb large volumes of gas gives rise to an amazing phenomenon: hydrogen or

oxygen contained in a hermetically sealed platinum vessel "leaks" from it when heated because gas molecules pass through the platinum walls like water through a sieve.

Platinum is important for measuring high temperatures. Extensive use is made of platinum resistance thermometers. The electrical resistance of a conductor (in this case platinum wire) increases with rise in temperature at a rate which is a constant value. This forms the basis of the resistance thermometer. The temperature is deduced from the measurement of resistance of the platinum wire connected to a resistance-measuring instrument.

Thermocouples are another type of a simple but very accurate thermometer. If two wires from dissimilar metals are welded together, electric current will arise in them when the junction is heated. The more intensive the heating, the greater the electromotive force in the circuit. Thermocouples are most often made from platinum and its alloys with rhodium or iridium.

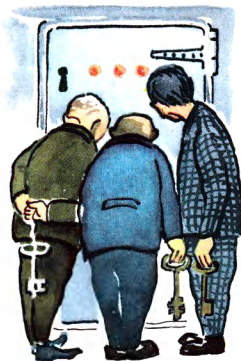
An alloy of platinum with iridium (10 per cent) was the material from which the *kilogramme* standard was manufactured in 1883. At present it is in the custody of the Mendeleyev Institute of Metrology housed in an inconspicuous building in Moscow Prospekt, Leningrad. The plaque over the entrance door bears the inscription in Russian and French: "USSR State Standards".

Constant temperature and humidity are maintained in the vault where the standard is kept and it can be entered only in the presence of three people: the institute director, the learned keeper of the national standards and the learned keeper of the given standard. Each of them has a key to only one of the three locks that will release the massive door only when all the keys have been inserted in the keyholes. The prototype kilogram is a cylinder 39 mm in height and diameter resting on a rock crystal stand under two glass hoods.

Every now and then the standard is put on the supersensitive metrological scales that reacts even to the slightest motion of air (such as human breath) to weigh standards against it. In order to safeguard the standard from the effects of outside traffic or the work of mechanical gadgets inside the building, however small these effects may be, the scales is mounted on a base going seven metres down. It is remote-controlled from a neighbouring room so as not to upset the constant temperature and humidity balance. All the precautions notwithstanding, the kilogram has lost 0.017 milligram in weight during the nearly one hundred years of its existence. But that change was so infinitesimal that in April 1968 it was again approved as the national standard kilogram.

Kept in the same vault, in a special case, is also the platinum-iridium bar, which only recently was the national standard metre. This unit of length equal to one-forty-millionth of the Paris Meridian was established in France in 1793. Six years later the first standard metre was made and is now in the custody of the Bureau International des Poids et Mesures in Paris. It bears the solemn inscription: "For all times, for all people". The metre became one of the most extensively used units of length. From 1889 until recently the exact replica of the Paris prototype, which was even made from a single melt, was the standard metre in the Soviet Union as well.

Scientists are constantly searching for ways of increasing the accuracy of the standards. As a result, the platinum-iridium bar was compelled to "resign" its "post" in 1960 when it was replaced by the light of a krypton lamp. The standard metre became a band of 1650 763.73 wavelengths of orange light emitted by the isotope krypton-86. But how is this standard used in practice? This is taken care of by a special instrument—interference



comparator—which determines whether the given number of wavelengths fits into the metre being compared with the standard.

Another basic unit the definition of which is associated with platinum is candela (new candle), the unit of luminous intensity. It is defined on the basis of the luminescence emanating from a horizontal tube cast in thorium oxide and immersed in molten platinum. Measurements are taken during the cooling of the platinum, since this period is characterized by a constant temperature ensuring the reproduction of the luminous intensity unit, candela, with the utmost precision.

Platinum is finding increasingly wider application in medicine. The special platinum electrodes introduced in blood vessels enable surgeons to diagnose many ailments and especially, heart diseases. Based on the electrochemical reaction of hydrogen and platinum, this method is termed platinum-hydrogen diagnosis and is used in many countries.

Doctors in Ohio (USA) have recently developed a fundamentally new method of

applying anesthesia. A platinum plate several centimetres long connects the signal cord with a storage battery. The patient's slightest movement causes an electric signal to be transmitted to the brain, blocking all sense of pain.

Thanks to its nonoxidizability platinum figures prominently in dentistry as well. The pure metal, however, is too pliant to be efficient in this field, but its alloys, characterized as they are by high strength, are excellent in dental fixtures. At the early stages platinum was alloyed with silver and nickel, but nowadays gold and platinum metals are used for the purpose. Combined with them, platinum, apart from being nonoxidizable, also becomes extremely wear-resistant.

Large amounts of platinum produced in the world today fall into the hands of

jewellers who have shown a special interest in it since the prices of this metal have topped the prices of gold several times over. Even before the First World War platinum rings, brooches, earrings, bracelet charms and other trinkets became fashionable (to please some money-bags this valuable metal is at times "employed" on dubious jobs: in chains for pet lap-dogs or cages for learned parrots). Jewellers also like platinum alloys because of their extra hardness and because they are a cheaper material and more easily available for people that are not so rich but are keen on fashion.

In the Soviet Union platinum has one very honourable duty: cast from it is the image of Vladimir Lenin, the founder of the Soviet state, on the Order of Lenin, the highest national award.

THE KING OF METALS AND THE METAL OF KINGS



King Midas makes a wish.— Hard nut to crack.— In the Valley of the Kings.— Semiramis' secret.— For the sake of convenience.— Alchemy and the Inquisition.— The Treasure of the Templars.— Where are the gold horses?— Atahualpa's ransom.— The Sun Temple.— The ocean takes its revenge.— "Gold-fever".— The Empress' collection.— Prince Gagarin's carriage.— Nikifor Syutkin's fate.— Replacing the gold-digger's trough.— Australian nugget.— Buddha's stone attire.— In deep secrecy.— Gold-eating bacteria.— The "alchemists" of the 20th century.— Archimedes exposes the swindlers.— Churchmen are fooled.— The clever cashier.— Niels Bohr's medal.— Eternally imprisoned.— Gold seals.— On the Atlantic seabed.

Gold! ... Never was a metal destined to play so sinister a role in the ages-old history of mankind. For the sake of gold blood-thirsty wars were waged, nations and states were annihilated and monstrous crimes committed. No words can adequately describe the sorrow and suffering caused by this beautiful yellow metal.

It would perhaps be correct to say that the first to suffer from gold was the Phrygian King Midas. This is how Midas' story is told in a Greek myth.

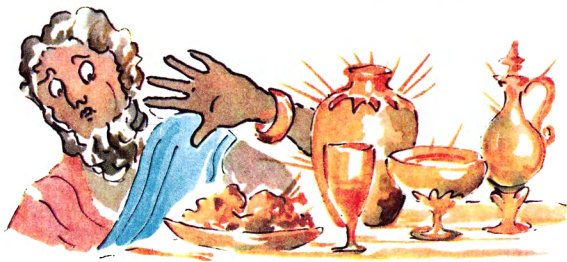
One day the god of wine Dionysus, son of Zeus, was wandering in the beautiful land of Phrygia accompanied by his numerous worshippers. By and by the drunk and jovial Silenus, Dionysus' favourite guardian and tutor, fell behind the rest of the merry-makers. He was found by Phrygian peasants who bound him with garlands of flowers and took him to King Midas. The King immediately recognized the genial old drunk Silenus and accorded him a royal reception. The feast in honour of the illustrious guest lasted for nine days. On the tenth day Midas himself took Silenus to Dionysus who was so glad to see him back that he offered the King to choose a reward.

"O great Dionysus!" exclaimed the happy Midas. "Command that everything I touch should become pure, brilliant gold!" The wish was fulfilled and Midas,

triumphant, hastened to his castle. On his way he broke a green branch off an oak and it immediately became gold, he touched an ear of wheat in the field and it turned into gold, he picked an apple from a tree and it sparkled with a yellow brilliance. He wanted to wash his hands, but water flowed from his palms like molten gold. Midas was overjoyed. But when an excellent meal was set on the table he realized what a terrible gift he had asked for. Horrified by the prospect of death from thirst and starvation, Midas cried, his arms outstretched to heaven, "Have mercy on me, O Dionysus! Forgive me, I beg you! Take back your gift!" The god commanded him to go to the fountain-head of the river Paktolus. There pure waters washed the awful gift away.

The Phrygian king was only the first in the long list of those who fell victim to the lure of gold. A recent case was a lady of venerable age who literally scratched her name with her teeth. This is what happened a few years ago.

Fuji Kanko, a Japanese tourist agency, installed a bath-tub of pure gold in a fashionable hotel of the luxurious Funabara resort. The fantastic charge did not dampen the passions around the gold tub and there were crowds of people who wished to take a dip in it. The tourist agency was raking in enormous profits.



But it also had its worries. Among other things, it had to hire an army of detectives to watch the clients, many of whom were not averse to wrapping a chisel or some other tool in their towels and, when left in the bathroom, tried to break off at least a small piece of gold "as a souvenir". The guards finally had to prohibit the "souvenir collectors" to take anything in, leaving them to their own resources. One gentleman forgot himself so much in his desperation for gold that he started to bang the gold tub with his heel using all his might and had to be treated for a badly injured ankle afterwards. But the record in avarice was broken by the lady we have mentioned. When her time in the bathroom was coming to an end she decided to bite off a piece of gold. But the "nut" was too hard for her and a few days later she was seen trying on a new dental plate: one has to pay for one's fun.

There is talk that the Fuji Kanko were so encouraged by their success with the bath-tub that they are now contemplating the idea of installing gold toilet bowls in their best hotels.

The idea is not new, as a matter of fact. This is how V.I. Lenin expressed his contempt for the bourgeois gold idol back in 1921: "When we win on a world scale, I think we will build several gold public lavatories in the streets of the biggest cities of the world. But until then we must be thrifty with our gold in the Russian Federation, we must sell it at a dear price and buy goods for it cheaply."

The history of gold is the history of civilization. The first grains of this metal fell into the hands of humans several thousand years ago, and almost immediately came to be considered precious. In ancient times Egypt was believed to be the richest country in gold. Excavations at the sites of former burial grounds support this view. "Gold sparkled everywhere with the first rays of the sun. There was gold on the floor, on the walls and in that far corner



where the sarcophagus stood near the wall. The gold was bright and with a resplendent lustre as though it had just left the goldsmith's hands ..." wrote in 1907 a member of the archaeological expedition which had made the first opening of an unknown pharaoh's tomb in the Thebes Valley of the Kings on the western bank of the Nile.

But, the tombs and burial vaults discovered by archaeologists contained only a very small portion of the truly countless wealth that ancient rulers had possessed during their lifetime. To win favour with gods Semiramis, the Queen of Assyria, ordered huge sculptures of them to be made from pure gold. One of the sculptures was nearly 12 metres high and weighed one thousand Babylonian talents (something like 30 tons). The statue of goddess Rhea was even more impressive: eight thousand talents (almost 250 tons) of pure gold had gone into it. The goddess was sculpted sitting on a throne which was protected by two big gold lions on its sides.

The first gold coins appeared approximately two and a half millennia ago. They were made in Lydia, a powerful slave-owning state in Western Asia Minor.

Lydia maintained extensive trade relations with Greece and her eastern neighbours. For the sake of convenience Lydians introduced a stamped gold coin—stater—one side of which showed a running fox, the symbol of the chief Lydian god Bassareus.

When Lydia was conquered by the Persian King Cyrus gold coinage was started in other countries of the Middle East as well. Among the most widely used pieces were the darics of the Persian King Darius which bore his picture as an archer.

The Middle Ages saw the flourishing of alchemy which became a universal obsession. Attempts to transmute baser metals into gold had been made from time immemorial but never had they been so widespread. Day and night fires were going in alchemist furnaces in the gloomy basements of stone castles, and mysterious iridescent liquids were bubbling in cauldrons and crucibles releasing noxious fumes.



In their search for the “philosopher’s stone” with which they could obtain gold, the alchemists and their protectors tried to be ahead of their competitors. On this fertile soil mistrust and hostility grew, giving rise to all kinds of ridiculous accusations of crimes committed. In 1440 Gilles de Laval, Baron de Rais (Retz), known in history by the sinister name of Bluebeard was charged with the murder of 800 maidens, from whose blood, the church claimed, he and his friend Fransula Prelatti extracted gold. On the insistence of the Bishop of Nantes, Gilles de Rais and Prelatti were turned over to the Inquisition and soon burned at the stake. Almost five centuries later, in 1925, excavations on the site of the castle where Gilles de Rais had once lived revealed a gold-bearing vein of quartz from which Prelatti had extracted the gold for the “Bluebeard”.

The Middle Ages wrote an impressive number of interesting pages into the history of gold.

In 1306 thousands of Parisians poured into the streets one day to see Jacques de Molay, grand master of the Templars, proceed to the order’s new temple. Hundreds of knights and thousands of armour-bearers, archers and servants in the retinue of the grand master, guarded not only the person of Jacques de Molay but also the fabulous wealth the powerful Templars had plundered in other lands, which was from then on to be kept in the unassailable castle encircled by a deep moat. The master of the temple could not know then that a year later King Philip the Fair who could not bear the thought of the Templars’ gold would order Guillaume de Nogaret, the just appointed Grand Inquisitor of France, to arrest him and his immediate subordinates. They were sentenced to be burned at the stake and were soon executed on a Seine island. But the King’s chief aim was to confiscate the incalculable wealth of the order and he

had personally seen to it that not a single gold coin should "stick" to the hands of his dignitaries or the inquisitors—all the gold was to become his property. One can only imagine the greedy King's disappointment when it was found that the order's treasure was not so large after all. Apparently the Templars had managed to hide the bulk of it beforehand.

Several centuries had passed. In 1745 a letter written by Jacques de Molay was discovered among old manuscripts. The Grand master must have managed to pass it before his death to the nephew of his predecessor Duke Guillaume de Boget. It said:

"The grave of your uncle, Grand Master de Boget, does not contain his remains, but the secret archives of the Order. There are also the relics: the crown of the kings of Jerusalem and the four gold figures of the Evangelists which adorned the Holy Sepulchre in Jerusalem and which had not fallen into the hands of the Muslims.

"The rest of the treasure is inside two columns across the way from the entrance to the crypt. Their capitals turn on their axes and open the caches".

After the execution of Jacques de Molay young Duke de Boget asked Philip's permission to remove the remains of his relative from the Temple. It is probable that he took the gold out of the caches and hid it in a new secret place.

This version seems plausible even if only because one of the columns in the church of the Temple was found really to be hollow. But where was the treasure moved? For more than 200 years this question has excited the minds of numerous treasure-seekers but no one has been able to lift the shroud off the mystery.

This is only one of the many old tales that later generations were not able to throw light on. Another is the fascinating legend about Khan Batu's gold horses.

Having amassed enormous amounts of gold during his conquests, Khan Batu



ordered that two life-size figures of horses (the weight of each was at least a ton and a half) be cast from gold. The two statues were erected in Sarai-Batu, the capital of the Golden Horde to symbolize the Khan's power.

Years had gone by and Batu's successor, his brother Khan Berke, decided to have himself a new capital city built that would be even more magnificent than the old one. When the construction of Sarai-Berke was completed Batu's gold horses were moved there, and subsequently passed down from one khan to the next. When Khan Mamai died he was buried at the wall of Sarai-Berke together with one of the gold figures.

Its "twin" had a different fate. A detachment of Russian warriors broke into Sarai-Berke and did not take anything there but the gold horse. The Horde sent a pursuit party and, on its advance, the Russians hid their priceless trophy on the bottom of some steppe river and, joining battle with the pursuers, were all killed to the man. The secret of the gold horse disappeared with them.

At the end of the 14th century the

armies of Timur (Tamerlane) ravaged Sarai-Berke and the horse which according to the legend had been buried with Mamai had also vanished. Had the horses really existed? Folk tales answer the question in the affirmative but the mystery remains.

Early in the 16th century when alchemic passions were still raging in Europe, Spanish and Portuguese conquistadors found an excellent "method" of gold extraction: they ruthlessly plundered the ancient states of America discovered by Christopher Columbus in 1492. The gold that had been collected by the Aztecs, Incas, Maya and other peoples of the New World poured into Europe.

The conquistadors had never dreamed of finding such fantastic treasure on American soil. When Fernando Cortez landed in Veracruz in 1519, American Indians, unaware of the sad lot that

awaited them, gave him, besides numerous ornaments, also two huge discs, no smaller than the wheels of a cart, one made of gold and the other of silver. The discs symbolized the Sun and the Moon.

In the great empire of the Incas gold was considered a sacred metal, the Sun God's metal. Colossal amounts of gold had accumulated in the temples. One temple was said to have its ceiling studded with open-work gold stars, gold dragon-flies, butterflies and birds, weightless in their flight above. The scene was of such breath-taking beauty that all who saw it trembled with awe and admiration.

Francisco Pizarro was one of the Spaniards who stepped on the land of the Incas at the beginning of the 1530's, a time of internecine wars on American soil. At first the Incas did not see anything bad for themselves in the appearance of the strangers. On the contrary, Atahualpa, the Great Chief of the Incas even thought they were gods that had come to help him to defeat his enemy.

Pizarro invited the Great Inca to a feast. Atahualpa arrived in a gold litter decorated with feathers. He was unarmed just like his suite. That was exactly what the treacherous Spaniard had counted on. He gave a sign and his men attacked the guests, taking Atahualpa prisoner and killing his suite.

They kept him under guard for a few days after which Pizarro promised him freedom if he would fill within two months the room where he was being detained with gold piled as high as his outstretched arm. The Great Inca gave his consent to that fantastic ransom amounting to almost 100 cubic metres of gold. Atahualpa's messengers were sent out to all corners of the land and soon files of bearers, bent low under their burden of gold vessels, statuettes, decorations and other luxuries were seen on all paths leading to the place of his imprisonment. The pile of gold was growing but still when the two months



were over it was not as high as Pizarro had commanded. Although the Great Inca tried to persuade Pizarro to wait only a little more, the Spaniard decided to execute him, fearing that he could later become a dangerous enemy.

At the moment of Atahualpa's death 11 000 llamas bearing gold were on the way to their leader. When the Incas learned that he was dead they hid their precious load in the mountains of Azangaro ("the remotest place"). The treasure that slipped through the Spaniards' fingers included an enormous gold chain. Legend has it that it took no less than 200 people to lift it.

But the Incas could not hide all their gold. The invaders captured and pillaged Cuzco, one of Peru's richest cities. Its pride was the gold-plated Sun Temple. The walls and ceiling of its central hall were decorated with gold sheets and the eastern wall was adorned by a gold disc, a representation of the face of God with eyes that were huge gems. When the first morning light fell on the disc the God's eyes flashed multi-coloured sparks creating an atmosphere of mystery. The temple was surrounded with a gold orchard. Everything in it—the trees, shrubs and birds—was made of gold. In the gold thrones among the gold trees were the mummies of the Sun God's sons, the Great Incas.

A few weeks after the arrival of Pizarro, the holy city of Cuzco had disappeared from the face of the earth. The conquistadors cynically wiped out the centuries-old culture of the Incas. They melted the priceless creations of ancient craftsmen into gold ingots which were more convenient for transportation across the ocean.

Every year over a period of two centuries flotillas of gold-laden galleons bound for the Iberian peninsula had been leaving the coasts of the New World. But time and again the ocean would take its revenge on the marauders and wrench the

stolen gold from their hands, hiding it forever in its depths.

In the summer of 1595 the *Santa Margarita* carrying gold and other valuables to the sum of 7 000 000 dollars sank not far from Florida. In 1643 sixteen galleons of the "golden fleet" were lost on their way to Seville in a terrible hurricane. According to historical documents, the total value of their cargo, mostly gold, was 65 million dollars. Another fourteen "golden fleet" galleons were smothered by the ocean waves in the vicinity of America's coast in the spring of 1715 when the area was swept by a hurricane of unprecedented force.

Historians maintain that the wreckage of about one hundred galleons rests on the bottom of the Caribbean alone. About as many ships went down at the south-western tip of Florida. The Bahama and Bermuda islands are the graveyard of more than 60 Spanish ships. And lastly, some 70 galleons found their end in the Gulf of Mexico. It would be no exaggeration to regard all those ships as gold caches, as every single one of them had incalculable wealth on board. Suffice it to say that the *Santa Rosa* alone carried 35 million dollars' worth of gold and other treasures from the palace of the great Montezuma.

These fantastic figures have weighed heavily on the minds of numerous adventurers for several centuries now. But since the search for gold on the ocean floor is attended with great difficulties, even more people were anxious to find the yellow metal in the ground.

No sooner had the presence of gold ores been discovered in some corner of the globe than thousands upon thousands of gold-diggers rushed there in a seizure of "gold-fever", a condition not described in a single medical textbook but brilliantly depicted by Jack London and Bret Harte.

People lost all that was human in them over a few grains of gold sand, brothers shot one another and sons killed their fa-

thers. That was what happened in Brazil in early 18th century; in sun-baked California, in the middle of the last century when crowds of gold-diggers flooded the area and a few years later, the deserts of Australia; in South Africa in the 1890's when the word "Transvaal" caused many eyes to flash; in the ice-bound Klondike where the "gold-fever" spread some ten years later and in Alaska, a remote piece of land which the tsarist government of Russia had sold literally for peanuts to the United States not long before.

There are photographs of "black snakes" working their way through snow-capped, polar mountains—endless files of people carrying their chattels on their shoulders and in sledges, people driven by a feverish

desire to fill their bags with gold. Alas, that was a dream that few of them could attain.

At the end of the last century vast gold deposits were discovered on the banks of the Lena, the great Siberian river. But the history of Russian gold is traced to earlier times.

The first Russian gold coins—the *grivniaks* (10 kopecks) and *pyataks* (five kopecks)—were put into circulation by Vasilii Shuisky in early 17th century. In 1730 Empress Anna Ioanovna decreed the coinage of the Russian *chervonets* (three-rouble gold piece). Wishing to be remembered as a generous monarch, she showered her courtiers with gifts of enormous value. One day she ordered the court jeweller to manufacture 16 gold tobacco-cases and to set several large gems in gold.

Under Yelizaveta Petrovna a 10-rouble gold coin was released. In honour of the sovereign's title it was called the *imperial*. Apparently Yelizaveta Petrovna was not indifferent to gold: numerous small and large chests full of gold coins were discovered in the palace after her death.

The aristocracy were intent on not falling behind their sovereign rulers. In 1711 Prince Gagarin, for one, who wished to impress society with his wealth, ordered himself a carriage to be made which was to be draped with foreign silks and to have silver-bordered wheels, and was to be driven by gold-shoed horses.

Gold production was started in Russia in the middle of the 18th century, after the peasant Yerofei Markov, who was in search of rock crystal for the Trinity Monastery, discovered in 1716 the first gold-bearing vein on the bank of the Berezovka river in the Urals. The Ural Mountains became the cradle of the national gold industry.

It was also in these parts that the biggest in this country, nearly 36-kilogram gold nugget was found by Nikifor Syutkin,



a workman of the Miass works in the basin of the river Miass in 1842. In St. Petersburg where the find was soon taken it had caused a whole sensation. Staff-Captain Schuman, the mine supervisor, was awarded the Order of Stanislav and Major Shirokshin, the mine manager, a bonus equal to his yearly salary. And Syutkin? What about him? One magazine wrote that Syutkin "let himself go, took to drink, began to come late to work and could not stop himself until one day, on the instructions of the Miass works administration, he was dragged, swollen and shabby, to the gold mine and was savagely birched in the presence of the mine workers summoned to the scene by the rolling of drums."

The working conditions at Russian gold mines were unspeakably hard. In summer the working day sometimes lasted for 16 hours. From dusk till dawn the workers, plagued by swarms of mosquitos and gnats, washed tons of sand on their primitive troughs without straightening their backs. Strikes were frequent and no wonder. One of them, which flared up at the Lena gold mines in 1912, went down in the history of the Russian revolutionary movement.

From the very first days following the 1917 Revolution the Soviet government attached great importance to the development of the gold industry. The young state of workers and peasants was in need of gold: enormous funds were required in order to implement the great plans of electrification, the development of the national heavy industry and the building of tractors and other farm machinery. Large consignments of metal and equipment had to be bought in the international market where commerce was conducted only in gold, which in Marx's words, was a "universal measure of value".

After the Revolution the Russian gold mines were supplied with new machinery and began to be run on a new basis. Once

a semi-handicraft enterprise, gold production had now become a leading modern industry.

Today one can come across a gold-digger's trough only in a museum. They have been replaced by mechanized dredges that are as tall as a four-storey building. More than 100 railway carriages are needed to move the 1400-ton units and components of a modern dredge. The biggest dredge designed by Soviet engineers is complete with automatic devices, remote-control equipment and TV monitors. Economists have calculated that this dredge (serviced by a crew of nine) does the work of 12000 workers. Separated from barren rock, minute grains of gold are further processed until small nuggets can be produced. But very often gold occurs in nuggets. We have already mentioned the biggest one discovered in Russia, as for the world's biggest, it was found in Australia and weighed around 112 kilograms.

Gold occurs sometimes in most unexpected places, like this one described in the episode below.

Near Thailand's capital Bangkok a huge statue of Buddha, brought from unknown parts by unknown people, had once been erected. About 40 years ago someone designed a saw-mill to be built on the spot and the statue had to be moved. When it was being taken down from its base it cracked despite all the precautions and deep inside the workers saw something glittering. The supervisors ordered the facing to be removed and a Buddha of pure gold weighing 5.5 tons was revealed to the stunned witnesses.

Specialists concluded that the monument was at least 700 years old. Most likely during one of the periods of internecine wars Buddha's owners put a stone "suit" on it and were later prevented from removing it. The statue worth about 5 000 000 dollars is now housed in the famous gold sanctuary of Bangkok.

A little more than 50000 tons of gold have been mined over the whole history of mankind. Is it much? It does not really seem so: geologists believe that the earth's crust alone contains something like 100 thousand million (!) tons of this metal. Apart from that, about 10 thousand million tons are dissolved in the water of the seas and oceans. The ocean reserves of gold are being constantly replenished: the rivers flowing through gold-bearing regions wash it out of the rock and take it down to sea. For example, the Amur alone dumps at least 8.5 tons of gold into the Pacific every year.

Attempts to extract gold from seawater have been undertaken more than once. Right after the First World War, Fritz Haber, a German chemist who was moved by a desire to ease Germany's burden of contributions, was one of the first to try it. In 1920 a committee to find ways of extracting gold from seawater was set up in deep secrecy in Dahlem on the subsidies of the bank and the Frankfurt Assay Department. Over the eight years of his tireless search Haber developed highly accurate methods of analysis enabling him to determine the presence of gold in concentrations down to 0.0000000001 gram per litre and ways of increasing the concentration 10000 times. It seemed the scientist's efforts would be crowned with success. But as often happens, subsequent careful analyses showed that the actual gold concentration in seawater was only one-thousandth of that anticipated by Haber. Clearly, his project was not worth developing.

With the present-day level of technology, however, this problem can no longer be considered insurmountable. Many firms in foreign countries have been studying possibilities in this field. It is likely that the ocean will become an inexhaustible gold-mine within the near future.

Another promising direction being today explored by scientists in France and the

USSR is the development of biometallurgical processes. Not long ago gold-devouring bacteria were discovered, and especially, certain mold fungi which are able to "suck" gold out of solutions while becoming covered with a thin film of gold. The film is dried and roasted, yielding minute amounts of this element. True this method is still confined to laboratory premises but scientists are convinced that living organisms can well be used to extract and concentrate gold from different kinds of mountain rock.

In our day it is also possible to obtain gold from other metals. Does it mean that the millennia-old dream of the alchemists has come true and the "philosopher's stone" has been found? The point is that the "philosopher's stone" has been adequately replaced by nuclear physics. By bombarding iridium, platinum, mercury and tellurium by neutrons in the atomic reactors, scientists "obtain" radioactive isotopes of gold. Linear or circular accelerators can also be used for this purpose: in them charged particles are accelerated by electric and magnetic fields.

If a joke is in place here, we can suppose that by now British physicists must have violated the law: King Henry IV had signed in the 14th century many times by now; it said that no one, however high his status, was allowed to turn base metals into gold. During the following several centuries it had proved impossible for anyone to violate the law although there were many who would have liked to. It was only in the 20th century that scientists were finally able to do it.

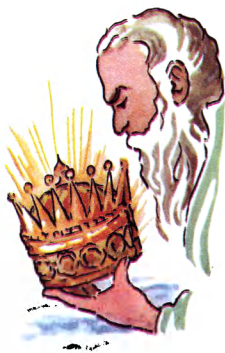
So much for the history of gold and its extraction. But what is this metal like and what uses does it have today?

Gold is one of the heaviest metals which was why Archimedes was able to expose the court jewellers who had made a gold crown for the Syracuse King Hieron. The King asked Archimedes to find out if the crown was of pure gold or some other

metal had been added to it. In our day even a schoolboy can cope with a problem like that. But in the 3rd century B.C. even the great Archimedes had to rack his brains over the King's request. The scientist weighed the crown and then immersed it in water and determined the volume of the displaced water. Having divided the figure for the crown's weight by that for the volume of water he had a number which was not 19.3 (the specific weight of gold) but smaller. That meant that the jewellers had stolen some of the gold replacing it by a cheaper metal.

Pure gold is very soft and pliant. A gold nugget not larger than a match-head can be drawn out into a wire more than three kilometres long or can be beaten into a transparent bluish-green leaf 50 square metres in size. One can leave a scratch on this metal by one's nail. That is why gold used by jewellers usually has additions of copper, silver, nickel, cadmium, palladium and other metals making it stronger. But when gold is worked in its pure form, considerable amounts of it are lost in dust.

A curious incident happened in the United States at the end of the last century. Across the way from the Philadelphia Mint there stood a very ancient church. When repairs were begun on it a resident asked if he could have the roof for 3000 dollars. The roof was so old that it was absolutely no good and the church community thought the customer was off his rocker. It could not resist the temptation of good money, however, and accepted the offer. The deal was made and the church ... was fooled. The buyer scraped the paint off the roof and burned it—the ash contained about 8 kilograms of gold that naturally cost much more than he had paid for it. What happened is that for many years gold dust had been escaping from the pipe of the Mint's smelter and settling on all surrounding objects, but most of all, on the church roof.



Another story is about a clever cashier in a big European bank. The incident took place on the eve of the First World War when most countries had gold money in circulation. Thousands of coins poured daily into the banks where they had to be sorted out, counted and sealed in paper. Usually all these operations were conducted on special wooden tables. One day a cashier spread a length of cloth on his table before beginning his working day. His bosses were thrilled by such neatness and for a long time praised him as a model to copy. Every morning the cashier took the cloth out of his desk and spread it on the table and when the day was over folded it and put it away. On Saturdays he took it home and on Mondays brought a new piece of cloth.

This was going on until one day the cashier's woman servant let out that her employer roasted the cloth on a frying pan every Saturday. The gold dust that had stuck in the fibres of the cloth melted into a tiny precious nugget.

One of the most important properties of gold is its amazing chemical resistance. It is not affected either by acids or by

alkalies. The threatening aqua regia (a mixture of nitric and hydrochloric acids) is the only substance that can dissolve gold. This property was once made practical use of by the Nobel Prize winner Niels Bohr. In 1943 when he had to flee the Nazi-occupied Copenhagen he dissolved his gold Nobel medal which he was afraid to have with him, in aqua regia, hiding the retort with the solution in his laboratory. When he came back after the liberation of Denmark he extracted the gold from the solution chemically and had a replica of the medal made.

Gold is often described as the "king of metals", highly valued, glorified and worshipped. But its fate is not one to be envied: gold is an eternal prisoner. Just think that the minute it is freed from the earth's depths it is imprisoned again in unassailable safes, armour-plated vaults and concrete-lined underground dungeons. One of them is Fort Knox encircled by several rows of barbed wire under a charge of 5000 volts where the bulk of the US gold stock is kept. Ten watch-towers equipped with sophisticated radioelectronic control devices are stationed on the

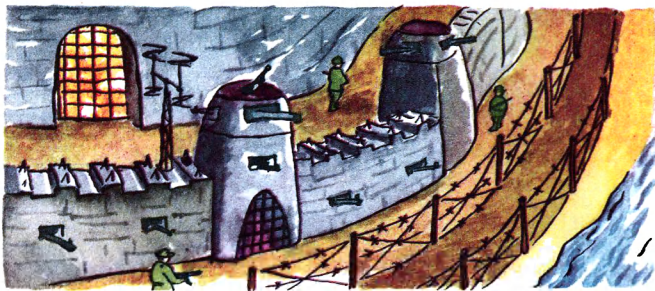
approaches to the Fort. The machine guns and rapid-firing field guns mounted in the watch-towers are trained on the target automatically. The Fort is divided into sections some of which can be flooded. Within minutes all sections, moreover, can be filled with noxious gases which effectively kill everything living. In the very centre of the Fort, America's gold is kept in a ferroconcrete hermetically sealed block fitted out with a 20-ton door and special locks. The electronic "eyes" do not "close" even for an instant. Not a single other prisoner in the world is guarded so vigilantly.

True at the beginning of 1975 Fort Knox had to part with some of its treasure. But it happened on the President's approval, after he had signed a decree allowing gold to be sold to private individuals (this had been prohibited since 1933). One day in January (1975) history's biggest gold auction was held in Washington during which nearly 56 tons of the precious metal were sold. But there was "something" left at Fort Knox, around 8000 tons.

Only a small amount of the gold produced is spent by dentists and jewellers, and still less is used for technical purposes. It must be said, though, that industry has lately shown a growing interest in gold. Electronics consumes more and more of the yellow metal as a material for the transistors and diodes. Owing to their exceptional chemical resistance, gold-platinum alloys go into the construction of equipment for synthetic fibre plants.

In electron devices commercially pure gold is used because of its ability firmly to "stick" in a highly rarefied state to copper which is in contact with it. The mutual diffusion of the two metals takes place at temperatures much lower than the temperature at which any of the two metals or any of their alloys melts. The very stable compounds produced as the





result are in technology termed "gold seals". Made from gold are the packing rings of the vital units of accelerators of charged particles; various joints in accelerator cavities and tubes are brazed with gold; gold effectively seals all loopholes through which air can get into the cavities owing to which an extremely high vacuum—thousands of millions of times lower than atmospheric pressure—is maintained. And the higher the vacuum the longer the life of the elementary particles.

Gold was used by the engineers who were responsible for the laying of the Transatlantic telephone cable in the mid 1950s. It must be said that until then transatlantic telephone communications had seemed a wild dream even though telegraphic messages had been cruising between Europe and America for more than one hundred years. The main difficulty was that the current transmitted by the telephone cable was dampened fast. The answer could be provided by amplifiers spaced evenly over the length of the cable and maintaining a constant current. In order to protect the amplifiers

from the destructive action of seawater it was suggested that some of their components should be gold-plated. Thus gold helped to solve an extremely difficult technical problem and in 1956 the first transatlantic telephone conversation marked this achievement.

Gold is doubtlessly destined to make a weighty contribution to the exploration of outer space. A few years ago Western mass media reported that the American satellites *Prospero* and *Ariel-4* intended for ionospheric research would have gold-plated exteriors. And considerations that had moved the Roman Emperor Nero to shoe thousands of his mules with silver have nothing to do with the gold plating in this case. Gold ensures efficient thermo-regulation of the satellites' sheathing, it does not oxidize and is transparent to ions, thus preventing dangerous ion accumulations fraught with various emergencies.

Industry's need for gold grows year by year. It can be stated with sufficient certainty that sooner or later this most valuable metal will leave the confines of the steel safes and make its way to plants and laboratories.

SILVER WATER



Exception from the rule.—Distant relations.—A mercury hammer.—The weight will not sink.—“Miraculous” treatment.—Tragedy on the Triumph.—Outlawed.—Good name restored.—Rome is buying mercury.—Genghis Khan’s exploits.—Inscription in the Achaemenides Palace.—In vogue.—Monarchs build laboratories.—Medieval “wizardry”.—Death by hanging or burning alive.—Underground experiments.—Caught in the campaign.—The cunning god of trade.—Montferrand’s creation.—Premature joy.—Green lipstick.—Ferdinand II recommends alcohol.—Difficult examinations.—Road in life.

More than 200 years ago Mikhail Lomonosov made a simple and clear definition of metals. He wrote: "Metals are solid bodies, malleable and lustrous." Indeed, iron, aluminium, copper, gold, silver, lead, tin and other metals we come across in life fully justify this definition. But there are no rules without exceptions and one of the 80 or so metals in nature is liquid under ordinary conditions. You must have guessed by now that we mean mercury. The example of mercury and its antipode, tungsten, illustrates the enormous range of properties characterizing metals. While tungsten melts at almost $3\,400^{\circ}\text{C}$ (it will be mentioned for the sake of comparison that the temperature of the fire in the hot zone of an open-hearth furnace does not rise above $2\,000^{\circ}\text{C}$), mercury remains liquid even under freezing temperatures and solidifies only at minus 38.9°C . Clearly, therefore, while belonging to one large family of metals, these two can be regarded as no more than "distant relations".

Mercury was frozen for the first time in 1759. In this state it is a silvery-blue metal not unlike lead in appearance. If mercury is poured into a mold in the form of a hammer and quickly cooled to a solid state, say, by liquid air, it will be possible to drive a nail in a board with this hammer. But it will have to be done very quickly because the "hammer" may melt in the user's hands.

Mercury is the heaviest of all known liquids, having a density of 13.6 grams per cubic centimetre. This means that a one-litre bottle of mercury weighs more than a bucket of water. If a weight-lifter had to put his steel weight not on the platform but in a reservoir full of mercury, the weight, no matter how heavy, would not sink but would be floating like a cork in water: steel is much lighter than mercury.

Man's acquaintance with mercury began in prehistoric times. This metal was mentioned in the writings of Aristotle,



Theophrastos, Pliny the Elder, Vitruvius and other ancient scientists. The Latin name for mercury is "hydrargium" (silver water or quicksilver) which was given to it by the Greek doctor Dioskorides in the first century A. D. There is nothing surprising in the fact that a physician should have been concerned with this metal in those remote times: mercury had long been known for its medicinal properties. True, sometimes its application for curative purposes was plainly of a doubtful nature. One case recorded in literature is of a volvulus treated by introducing in the patient's stomach 200-250 grams of mercury. According to the "healers", mercury's considerable weight and mobility were a good guarantee that it would quickly travel through the intricate convolutions of the intestines and smooth out the twists by its sheer mass. The results of such treatment can well be imagined.

There are more reliable ways of treating volvulus in our day, but still different mercury compounds are widely used in medicine. Thus, mercuric chloride (corrosive sublimate) has disinfecting

properties; calomel can be used as a laxative; mercusol is a diuretic; and some mercury ointments are used for the treatment of skin diseases and other ailments.

It must be emphasized, however, that mercury compounds and vapours can cause acute poisoning. For example, in 1810 more than 200 people were poisoned by mercury leaking out of a barrel on board the British ship the *Triumph*. This is why in the Soviet Union and in some other countries some processes involving mercury and its compounds, such as the production of mercury paints, are prohibited. In cases where it is impossible to do without mercury various preventive

measures are taken to protect workers.

Nature is not richly endowed with this metal. Sometimes it occurs in the native state in the form of tiny droplets. The main mercury-bearing mineral is cinnabar, a beautiful stone with red spots resembling blood. A curious incident is associated with cinnabar. We have already mentioned that lately geologists have been training dogs for geological prospecting. So one day when training was completed, something like an "examination" was staged for the dogs. Their assignment was to find cinnabar among the many other specimens of rocks. The dogs found this mineral easily but all of them went further: as though by previous agreement they all took pink calcite for cinnabar. At first the examiners chuckled condescendingly but then decided to find the cause of the universal mistake. To their amazement, inside the calcite they found impregnations of cinnabar. The good name of the four-legged geologists was restored.

The world's biggest mercury deposit is at Almaden in Spain which until recently produced 80 per cent of the world's mercury. Pliny the Elder wrote that Rome bought nearly 4.5 tons of mercury in Spain annually.

The oldest in this country is the Nikitovskoye deposit in the Donets Basin. There ancient mining excavations and old working tools—stone hammers—have been discovered at different depths (down to 20 metres).

Even older is the Khaidarkan (Great Mine) in the Fergana Valley in today's Kirghizia (Central Asia) where numerous traces of ancient workings have been preserved: large excavations, metal wedges, lamps, clay retorts for the firing of cinnabar and large dump heaps that were formed during kiln works.

Archaeological excavations show that mercury had been produced in the Fergana Valley for many centuries in the past and it was only between the 13th and 14th



centuries that it was stopped after Genghis Khan and his successors had destroyed the centres of crafts and trade and the population began to lead a nomad life.

Other mercury deposits were worked in Central Asia as well. The inscriptions on the walls of the Palace of the Achaemenid dynasty in Suzy (6th-4th cent. B.C.) indicate that cinnabar used in those times mainly as a paint was brought there from the Zeravshan Mountains situated on the territory of what today are the Central Asian Republics of Tajikistan and Uzbekistan. Apparently mercury was mined there as early as the middle of the first century B.C.

The work of miner was difficult and dangerous. Kipling once said that he would prefer a most violent death to work in mercury mine where teeth crumbled. Numerous skeletons are found in the labyrinths of ancient mining excavations. Thousands of lives were the price for the red stone splattered, as it were, by the blood of those who attempted to take it away from the mountains.

Mercury production saw a steep rise in the Middle Ages during the upsurge of alchemy. The alchemists' interest in quicksilver was explained by the fact that one of their theories placed mercury, sulphur and salt in the category of "original elements" and "maternal qualities" were ascribed to mercury: "... heat dissolves ice into water which means that it comes from water; metals are dissolved in mercury, which means that mercury is the primal state of these metals".

Equipped with this "sound scientific theory" the alchemists had only to find the "philosopher's stone" by means of which they could begin to transmute mercury into gold and get down to business. But what a pity! The search for the "philosopher's stone" dragged on and on, despite the fact that such illustrious figures as the English King Henry VI and the Emperor of the Holy Roman Empire Rudolph II

were interested in it, along with many other European monarchs who had set up big alchemic laboratories at their courts.

But it must be said for truth's sake that the alchemists' researches did bring some results. For example, one of them working at the court of Henry VI discovered that copper rubbed with mercury acquired a silvery tint and the King did not lose time in "introducing" the discovery in practice; he ordered the minting of a large consignment of mercury-coated copper coins passing them for silver ones, and pocketed an impressive sum of money.

Persons who claimed to have unravelled the mystery of the "philosopher's stone" appeared in many countries from time to time. Some were honest but confused scientists, but more often they were swindlers who "knew" many ways of making artificial gold.

One of the ways was for the alchemist to place a few grains of gold in a crucible before he began his demonstration and then show the audience how he stirred molten lead or mercury with a wooden stick. Some of the gold would dissolve, naturally, and people would see traces of gold which would prove, or more correctly, falsely testify that the miraculous transmutation had taken place.

But rumours about such "wizards" would spread, reaching the country's ruler sooner or later, and then they would either have to admit fraud or organize gold production on a large scale at court, and there the wooden stick would be of little help.

The exposed alchemist would usually be hanged as a counterfeiter—on a gilded gallows and wrapped in a metal-spangled robe. There were other forms of execution too. For example in 1575 the Duke of Luxemburg had Maria Zieglerin, a woman-alchemist burned at the stake because she had refused to disclose the composition of the "philosopher's stone" which she could not do for obvious reasons

but insisted that she could.

Some time later alchemy was anathematized by the Catholic Church and officially banned in Britain, France and other countries. But alchemic experiments continued in secret. The executions also continued. Caught in the campaign was the French chemist Jean Brillo who was executed only because he had been studying the properties of elements in his laboratory. His experiments had seemed suspicious which was enough to seal the scientist's fate.

The name "mercury" cropping up in alchemic recipes was given to the metal in the times of ancient Rome. That was due to the ability of mercury droplets to move fast on a smooth surface which resembled to the Romans the cunning and resourceful god Mercury, the protector of trade. Many other elements in the alchemic literature were concealed under various symbols: gold bore the symbol of the Sun, iron of the planet Mars, copper of the planet Venus, etc. In this way the alchemists were able to conceal their knowledge from people who were not familiar with their symbolics.

The ability of mercury to dissolve many metals and form amalgams was noticed even before our era. In later times amalgams were used for depositing a very thin layer of gold on copper church cupolas. This method was used for the gilding of the St. Isaac Cathedral, the magnificent architectural monument created in St. Petersburg between 1818 and 1858 under the project of August Montferrand.

More than 100 kilograms of pure gold was deposited by amalgamation on copper sheets covering the gigantic (about 26 metres in diameter) cupola of this cathedral. The surface of the copper sheets was carefully degreased and polished and then covered by amalgam—a solution of gold in mercury. After that the sheets were heated in special braziers until mercury evaporated, leaving a thin film (a few

microns) of gold on the copper. But the light bluish-greenish streak of mercury vapour curling up quietly and seeming to vanish without trace was poisonous to the workers engaged on the job. Although under the "safety rules" of that time they were using glass hoods these "workclothes" could not protect them from poisoning and they died a terrible death. According to contemporaries, the gilding of the cathedral claimed 60 lives.

But not only tragic incidents are associated with amalgams. There are funny stories as well. One is about a scientist who at the beginning of this century tried to obtain gold from mercury by passing powerful electrical discharges through mercury vapour. He had put in much time and effort and finally the first traces of gold appeared in mercury. One can only imagine his joy and then his disappointment when he realized that the gold he found in mercury had peeled off the rims of his own glasses. Touching his glasses with his hand on which tiny droplets of mercury had settled the scientist transferred gold in the form of amalgam from his fingers to the mercury he was studying.

Today too amalgams are used in certain cases for gilding (it goes without saying that this is achieved without human sacrifices) in the making of mirrors, in dentistry and in laboratory work.

Pure mercury is widely used in technology. In the chemical industry, for one, it takes part in the production of chlorine, caustic soda, and synthetic acetic acid. Mercury-vapour rectifiers are very reliable and have a long life. Mercury switches ensuring instantaneous opening and closing of electrical circuits are used in automatic control and measuring equipment.

Quartz-mercury lamps creating a powerful ultraviolet radiation are applied in medicine to purify air in operating theatres and for radio-therapy.

In 1922 Jaroslav Heyrowsky, the Czech chemist, developed the polarographic method of chemical analysis in which mercury plays an important role. For this work he was awarded the Nobel Prize.

Rarefied mercury vapour with an addition of argon is used to fill luminescent lamps (mercury vapour lamps). Such lamps were installed in Gorky Street (Moscow) in 1937, but soon they had to be discarded because of the deathly pale light they emitted, giving an unpleasant greyish colour to people's faces and making lipstick look green instead of red.

Later it was possible to develop special substances—luminophors—that were deposited on the inside walls of the lamps, giving the light different hues, particularly white, which is very close to daylight.

Mercury is the main component of many physical instruments—manometers, barometers and vacuum pumps. But of course the most widely used are the thermometers.

In the 17th century when the first thermometers were invented, the thermometric liquid in them was water. But water froze under low temperature shattering the glass container and the thermometer was ruined. Ferdinando II, Grand Duke of Tuscany, was apparently intimately familiar with alcohol, since it was he that had suggested it as a replacement for water in thermometers. The thermometers became more reliable, but the quality of alcohol was not always the same, owing to which temperature readings were often widely discrepant. The French physicist Ammonton was the first to use mercury for measuring temperature. He was followed a few years later by the German physicist Fahrenheit who created his own thermometer with a scale still in use in Britain and the United States.

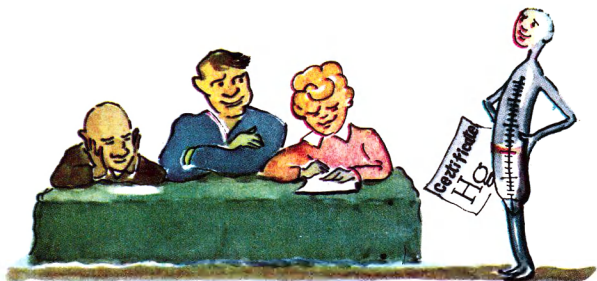
Mercury thermometers have the widest application today, a fact that dictates the



various thermometer designs, and particularly the diameter of the capillary along which mercury flows. The medical thermometer has the thinnest capillary—0.04 mm. To make this mercury column visible to the unaided eye the capillary is made in the form of a trigonal magnifying prism with a white enamel coating deposited on its back wall—a “screen”.

Since the mercury column must not drop unless shaken, the capillary must have a necking. But the trigonal prism is so thin as it is that it cannot be narrowed any more. Hence, a small necked cylindrical tube is fused to it below.

Mercury used in thermometers must be extra-pure since even microscopic impurities may substantially distort the readings. Therefore the metal is specially treated:



washed, distilled and only then pumped into the capillary.

It must be emphasized that despite its brittleness glass is irreplaceable in thermometers. For example, transparent plastic cannot be used here because it lets through oxygen, which is destructive for mercury, like a sieve.

The filling of the capillary with mercury is a very important operation because no oxygen must be let in. In the past when this was done manually both ends of the capillary filled with mercury had to be warmed up alternately for several weeks running so that the air bubbles could be removed from it. But today this operation is efficiently carried out by machines.

Before being allowed to do their "job" the thermometers are carefully tested and checked. And some of them have a sad end: they are rejected as defective and immediately thrown into the wastebasket. But the thermometers that have passed all the "examinations" and been given a "certificate"—the factory stamp—

guarantee 100-percent accuracy. The "unbiased" drop of mercury contained in a glass capillary will faithfully serve the needs of science, agriculture and medicine.

The history of mercury production is centuries old. Once mercury ore was roasted in earthen pots and mercury vapour was condensed on the leaves of freshly cut trees placed near the pots in brick chambers. Modern works are equipped with continuous mercury production units. The operator only has to push a remote-control button for tons of mercury concentrate to fill the hopper of a vast electric furnace. At a temperature of hundreds of degrees mercury begins to evaporate from the concentrate. The vapour is then cooled and the metal is channelled into a special storage tank.

Subsequently the metal is refined and poured into steel containers each holding 35 kg. Especially pure mercury is poured into porcelain vessels, 5 kg in each. In these vessels it is kept at storehouses from where it begins its working career.

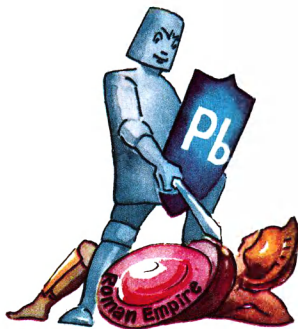
THE METAL THAT DESTROYED ROME



Clever geese.—The patricians' lot.—In the service of the Inquisition.—The secret of the Brahmins.—Screams of pain on the Bridge of Sighs.—A weighty argument.—Anti-knocking ability.—Leaden clouds.—“Made in Rhodes”.—Fire in the Athens port.—Can miracles happen?—Poisonous “sugar”.—The good and the bad side.—A unique porthole. A find under the ashes.—The library of King Ashurbanipal.—How old mountain rock is?—Green light for the prospectors.—One per 10 000 000.—Why all that mystification?—“Family” ties.—The cat ... was a cat.

That Rome was saved by geese is common knowledge. The good birds noticed the advancing enemy in time to announce his coming in loud piercing cries and warn of the danger. That time the city escaped unharmed: it was destined to fall later. Why did the fall of the once powerful Roman Empire take place? What destroyed Rome?

Some American toxicologists maintain that the end of Rome had been caused by lead poisoning, a result of the use of dishes set in lead and of lead cosmetic paints by the Roman aristocracy. Owing to the systematic poisoning by small doses of lead, the average life span of the Roman patricians was not more than 25 years. People of the lower classes, according to this theory, were not subject to lead poisoning so much because they had no expensive dishes and did not use cosmetics. But on the other hand they too used the famous water main which had once been built by Rome's slaves and which, as it is well known, had pipes made of lead. People were dying and the empire was going into a decline. It goes without saying that lead was not the only factor responsible for that state of affairs. There



were also serious political, social and economic reasons. But still there is a lot of truth in the American theory: the remains of ancient Romans found at archaeological excavation sites contain large quantities of lead.

All soluble compounds of this element are poisonous. It has been found that the water which fed ancient Rome was rich in carbon dioxide. Reacting with lead it forms lead carbonate which readily dissolves in water. Introduced even in minute doses in the human organism lead is retained by it gradually replacing the calcium in the bones and giving rise to chronic diseases.

But the destruction of Rome is not the only crime on the "conscience" of lead. Many "shady dealings" are attributed to it. When the Inquisition was rampant the Jesuits used molten lead as a means of torture and execution. In India even as late as the beginning of the last century a person belonging to a lower caste and caught eavesdropping on Brahmins during the reading of sacred books, intentionally or not, had molten lead poured into his ears (since time immemorial the priests of Babylonia, Egypt, and India had kept their knowledge in deep secrecy in order to be able to exercise power over their people).

Surviving in Venice is the notorious mediaeval state prison connected with the Doge's Palace by the Bridge of Sighs. In the old days the prison's attic had cells under a lead roof for especially dangerous criminals. In summer the prisoners were scorched by unbearable heat and in winter, they were dying of cold, and their screams of pain could be heard on the Bridge of Sighs.

Since firearms had been invented, lead began to be used for lethal bullets and was the weightiest argument in settling controversies between hostile parties. It was lead that decided the outcomes of major battles and small-time gangster fights.

An impression may be created that lead

is a metal the use of which spells nothing but danger and that humanity's chief concern should be to get rid of this wicked element which has already caused so much misfortune and suffering. But far from attempting to get rid of it, humanity is constantly developing lead production. Of all the nonferrous metals only aluminium, copper and zinc are produced in larger amounts.

Then what is the good side of lead?

History has recorded plenty of examples of nations waging just wars for freedom and independence and being helped by lead in their struggle. In order to be confident of the impregnability of one's country's borders it is necessary not only to have mettle but also lead. The military significance of lead is enormous.

There was a dramatic increase in lead production at the beginning of the century when the rapid advance of technology led to the development of motor vehicles, submarines and planes, and to the rise of chemistry and electrical engineering.

Approximately one-third of the world lead production is used for the manufacture of storage batteries, the grids for which are made from an alloy of lead and antimony and the active mass from a mixture of lead and litharge (yellow lead).

The fuel industry is among the major users of lead. Before gasoline is ignited in the engine, it is compressed and the greater the compression the more economical the engine is. But under heavy compression the gasoline detonates without having been ignited. Naturally this cannot be permitted. Tetraethyl (anti-knock) lead was summoned for help. Added to gasoline, this substance (less than 1 gram per litre) prevents detonations, ensuring that the fuel burns evenly, and what is even more important, only when necessary.

Since tetraethyl lead is very poisonous the gasoline containing it is dyed pink to distinguish it from common gasoline.

Regretfully, considerable amounts of poison are discharged by motor engines into the atmosphere together with the exhausts. According to scientists at the California Institute of Technology (USA), whole clouds of lead are transported over the heads of residents of big cities (as you see the expression "leaden clouds" can justly be understood as "lead clouds"): in one year nearly 50 000 tons of lead formed mainly from the lead anti-knock (this is what 1 gram per litre means!) precipitate over the seas and oceans of the northern hemisphere alone. The "motor-born" lead has even been discovered in Arctic snow. Obviously, tetraethyl lead must be replaced by something else, but it has not been possible so far.

In electrical engineering lead is used as a reliable and adequately elastic sheathing for the cables. Considerable amounts of it also go into various solders.

At chemical and nonferrous metals plants lead sheathing is used for the inner surface of chambers and towers involved in the production of sulphuric acid and also for pipes, pickling baths and electrolyzers.

The bearing alloys of lead with other metals are employed in many machines and mechanisms. Alloyed with antimony and tin it is included in the composition of the type metal.

In glass and ceramics making lead is essential for the manufacture of cut glass and special glazes. The oxides and salts of lead are indispensable in the varnish-and-paint industry. Lead paints were known in old times too.

Even 3 000 years ago people knew how to prepare white lead. The Rhodes island was the biggest exporter of it in those times. The method used to make the paint was not very sophisticated but reliable. A solution of vinegar was poured into a cask, branches of shrubs were arranged over the solution and pieces of lead were put on top. After that the cask was covered tight. Opened after a while, the



lead would be found with a white substance—white lead—deposited on its surface. It would be scraped off the metal, packed and taken to other countries.

One day fire broke out on a ship loaded with white lead and moored in the Athens port of Piraeus. The artist Nicias, who happened to be in the vicinity and knew there was paint on the burning ship (and paints were expensive then), went on board wishing to save some casks, even if one. But to his utter amazement, he found that the charred casks contained not white lead but some thick substance of a bright red colour. He seized one and hurried to his workshop where he discovered the contents to be an excellent red paint. Later it was called red lead and was obtained by roasting white lead.

Icons and paintings done in lead paints dim with time but it is enough to wipe them with a weak solution of hydrogen peroxide or vinegar for the paints to look fresh and bright once more. Churchmen knew about it very well and liked to fool believers performing a “miracle” before their eyes and making the icons “come alive”.

Lead compounds are used in medicine

as astringents, antiseptics and analgesics. Lead acetate (Goulard water) is known as the sugar of lead for its sweet taste. It must never be forgotten, however, that this “sugar” can cause a bad poisoning.

It is for good reason that protective measures are taken in shops and laboratories where employees work with lead or its compounds. Hygienists and labour safety engineers see to it that the content of lead in the atmosphere should not rise above the permissible level of 0.00001 milligram per litre. Not long ago lead-poisoning was an occupational disease of workers at lead smelters and printing shops. But not any more: improved production technologies and measures ensuring adequate ventilation and dust removal have almost completely ruled out conditions induced by lead poisoning.

Paradoxically though it may seem, lead not only poisons, but also offers protection. Metallic lead has been proved to be one of the most opaque materials for radioactive and X-rays. Try holding a radiologist's apron or gloves—you will be impressed by their weight: they are made from rubber mixed with lead which traps the extremely dangerous X-rays and

protects the organism. The grain of radioactive cobalt used in the cobalt gun to treat malignant tumours is also safely sealed in a lead bulb.

Lead screens are vital in the atomic power industry. Glass containing lead monoxide can also serve as a protection against radioactive radiation. Such glass makes it possible to control the work of the reactor handler of a nuclear installation. The atomic centre in Bucharest is equipped with a porthole made from lead glass one metre thick and weighing more than one and a half tons.

The lead content in the earth's crust is not so high—thousands of times less than the content of aluminium or iron. Nevertheless, man became familiar with it in very remote times—something like 7000-5000 years B.C. Unlike many other metals, lead has a low melting point (327°C) and occurs in nature in the form of rather unstable chemical compounds. This is why it was sometimes produced by chance.

A case in point is an incident recorded in America when a rich lead deposit was discovered as a result of a forest fire: big lead nuggets were found under the layer of ashes. The fire had "smelted" it from the ore deposited beneath the roots of trees. Very likely that was how the first lead had gotten into the hands of our prehistoric ancestors. The lead figurine coming from Egypt and kept in the British Museum is believed to be the oldest sample of lead that has come to us from antiquity. Ancient lead slag heaps are still found in Spain where Phoenicians developed the Rio Tinto lead-and-silver deposit in the third millennium B.C.

In the library of the Assyrian King Ashurbanipal (VII century B.C.) there are copies of Babylonian manuscripts dating approximately to the year 2000 B.C. One of them includes a hymn to the God of Fire: "Oh great God, you melt copper and lead, you purify gold and silver." During excavations in the city of Ashur archaeol-

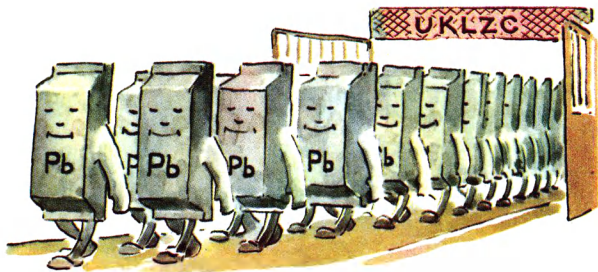


ogists discovered a lump of lead weighing 400 kilograms. They referred its origin to the year 1300 B.C.

One of the methods of determining the age of mountain rock and archaeological finds is associated with lead. Most types of rock and minerals contain small amounts of radioactive elements. The natural cycle which has lasted for thousands of years has caused some elements to decay and others to originate. The constant process of transformation that some metals undergo results in the formation of radium which, for its part, also disintegrates, gradually turning into lead. Given the amount of radium contained in a certain rock and the amount of lead formed every year, it is possible to determine the age of the rock. For example, it was found that the coal deposits of the Donets Basin were formed about 300 million years ago.

Traces of ancient lead workings have been discovered in the Soviet Union in Altai, the Transbaikalia area, and in the Far East. In some cases lead ores are discovered anew in these regions.

The 13th century sources mention the



use of lead for church roofs and for seals attached to documents.

The first attempts to start industrial lead production were made at the end of the 17th century by the well-known merchants and industrialists Stroganovs who had found lead ores on the bank of the Tobol in Siberia. It is known that in 1695 the specimens of the ore they discovered were sent to Germany for analysis.

An upsurge in the development of mining and metallurgy was registered in the epoch of Peter I who encouraged the work of miners and prospectors in every way. In 1704 considerable reserves of lead and silver ores were discovered in the Nerchinsk region (Transbaikalia area) and the first state enterprise was commissioned there in 1708. In the 18th century several deposits of lead, silver and zinc were found in Altai (Zmeinogorsk, Zyryanovsk and other deposits) which led to the construction of a number of new plants. The lead-smelting works in Barnaul turned out the first metal in 1732. In the years that followed Altai came to play a noticeable role in the world mining industry in both the scale and technical standard of production. Many leading specialists of that period worked at Altai plants. Some of them had been invited by the Russian government from the Saxon

town of Freiberg even then famous for its Mining Academy. A lead ore deposit discovered by the German mining engineer Philip Ridder in 1786 was named after him (the town that sprang up on the spot also bore his name till 1941 when it was renamed Leninogorsk). By the end of the 18th century the Altai works had put out more than 63 000 tons of lead.

In the middle of the 19th century the Caucasus also became one of the centres of silver-lead production. There the Sadon deposit known even in the times of Queen Tamara began to be developed. Later the Alagir silver-lead works was built nearby. It played a prominent role during the Crimean war of 1853-1856.

The construction of the zinc-lead works in Vladikavkaz (today Ordzhonikidze) began in 1898 and was completed in 1909. During the same period the rich lead-zinc ore reserves were being developed in Tetyukhe (the Far East).

On the eve of the First World War most nonferrous metallurgy enterprises were leased to foreign capitalists. The Tetyukhe mines were managed by Germans, the Altai works and mines by the British and those in the Caucasus by Belgians. The ruthless exploitation of the mineral resources had brought lead production onto the verge of collapse. In

1913 Russian factories met only 1.5 per cent of the country's need in lead.

Under Soviet government a powerful lead industry was set up which not only fully took care of the national economy's demand for lead, but made it possible to export it. Metallurgists in the Soviet Union and abroad are well familiar with the UKSZK trademark (Ust-Kamenogorsk Lead-Zinc Combine named after V. I. Lenin). This lead has been registered at the London nonferrous metals stock exchange market as a commercial quality standard (the same honour was accorded to cadmium). The lead works in Chimkent (Kazakhstan) turns out excellent metal as well. This works was the first to introduce the amalgam refining method developed by Kazakh scientists. For the first time in world metallurgy it has become possible to produce super-pure lead: it contains only 0.00001 per cent of impurities. This means that in one ton of this metal it is possible to "scrape up" only one-tenth of a gram of all alien elements taken together. A metal of a quality high as this will always have enough to do in the semiconductor and laser industries.

We could have ended the chapter on lead here, but for one detail we have so far omitted: the origin of its name. The word *svinets* (Russian for lead) apparently comes from *svinka* (diminutive for *svinya*, pig) as lead nuggets used to be called. (As a matter of fact, today they are also called *chushki*, another word for pig.) But before becoming *svinets* this metal lived by other names.

Probably you remember the Soviet writer Samuil Marshak's fairy-tale about a cat which was first called sun, then cloud, then wind, then mouse and finally a cat. Something like that happened to lead too.

If you take a look in Dal's *Explanatory Dictionary of the Russian Language*, you will see that the Russian proverb "word is tin" (*slovo—olovo*) did not actually mean tin (*olovo*), but lead (*svinets*), a heavier, hence more meaningful, metal (word). And the proverb itself is used to describe a word that is weighty, true and trustworthy. But why all that mystification? Wouldn't it be simpler to say "word is lead" (*slovo—svinets*)? The point is that in the past lead was called tin in Russia. Tin proper appeared later and at first it was mistaken for lead (these metals indeed have something in common). When finally people learned how to distinguish between the two the old name *olovo* stuck to the new metal and the old one was named *svinets*.

But that confusion had left its impression on the language. In the Ukrainian a pencil is called *olivets* or *olovets*, although pencils had never been made from tin and lead sticks were indeed used in the old times for writing.

These two metals were also confused by the ancient Romans, among others. They called lead "*plumbum-nigrum*" (black lead) and tin, "*plumbum-candium*" (white lead). Tin was brought to ancient Rome from Cyprus which Romans called "*Candia*".

"Family" ties also connect lead with molybdenum. Translated from the Greek "*molybden*" means lead. It appears that ancient Greeks confused the minerals of these metals—galenite and molybdenite—and called both "*molybdenum*". But when centuries later a new element was obtained from molybdenite it assumed the old Greek name for lead.

Lead became lead in the long run, and now it can feel safe about its name: "a cat was called a cat".

THE FUEL OF THE TWENTIETH CENTURY



In honour of the seventh planet.—The mosaics of ancient Romans.—The cards are shuffled.—Brilliant prediction.—Becquerel is waiting for the sun.—Discoveries in an old shed.—Mistake in the encyclopaedia?—Sensational reports.—The “boys” get an idea.—Where did lanthanum come from?—Incident in a barber’s shop.—Where is one to get neutrons?—Useful “greed”.—The “match” has been found!—Down the Dynamo Metro Station.—A drop in the ocean.—In old Chicago.—Time for lunch.—Nervous driver.—Fermi suppresses his smile.—The day that became black.—The first step.—The atomic ice-breaker lays its first trail.—“Marine” uranium.—A “parcel” to the Sun.—Radiant future.

It is hard to say what name the German chemist Martin Klaproth would have given the element he discovered in 1789 had not an event occurred a few years previously which had excited all sections of society: the discovery of the seventh planet of the solar system. Observing the star-studded sky through a home-made telescope in 1781, the British astronomer William Herschel discovered a luminescent cloud which he first took for a comet but then became convinced that what he saw was a new, hitherto unobserved, seventh planet of the solar system. He named it "Uranium" in honour of the Greek sky-god Uranus. Deeply impressed by the discovery, Klaproth named his new element in honour of the new planet.

Some fifty years later (in 1841) the French chemist Eugene Peligot extracted the first metallic uranium. The industrial world was indifferent to the heavy and comparatively soft metal. Its mechanical and chemical properties attracted neither metallurgists nor engineers. Only the glass-blowers of Bohemia and porcelain and faience makers of Saxony liked to use its oxide to obtain the beautiful yellow-green or velvety black colours.

Even ancient Romans knew about the "artistic gifts" of uranium compounds. During excavations near Naples archaeologists unearthed a fresco of inimitable beauty. What was especially striking about it was that in two thousand years the glass had remained practically undimmed. A chemical analysis revealed that it owed its long life to uranium oxide it contained.

Thus, while the oxides and salts of uranium were "doing socially important work", pure uranium was of practically no interest to anybody.

Even scientists had a very vague knowledge about this element: the available information was scanty and sometimes simply wrong. For example, it was believed that the atomic weight of uranium was something like 120. When

Dmitry Mendeleyev was working on his Periodic Table this figure was the source of confusion: uranium's properties were such that it would not fit into the place where an element with this atomic weight was supposed to be. The scientist then decided, contrary to the opinion of many of his colleagues, that the atomic weight of this element should be 240 and moved it to the end of the Table. Subsequent experience proved that the great chemist was right: the atomic weight of uranium is indeed 238.03.

But Mendeleyev's genius went even further. Even as early as 1872 when many scientists considered uranium a ballast against the background of many valuable elements, Mendeleyev predicted a truly radiant future for it: "Among all the known chemical elements uranium is noticeable for its greatest atomic weight ... The highest of the known concentrations of mass existing in uranium ... must be the basis for outstanding special features ... Convinced that the study of uranium, all the way from its natural sources, will yet result in many new discoveries, I should unhesitatingly recommend those searching for new subjects of research to devote their special attention to uranium compounds."

The brilliant prediction came true in less than twenty-five years: in 1896 the French physicist Henry Becquerel made a discovery which can rightly be included among the greatest scientific breakthroughs ever made. This is how it happened. The scientist had long been interested in the phenomenon of phosphorescence (a form of luminiscence) inherent in substances. One day he decided to make use for his experiments of one of uranium salts (potassium uranyl double sulphate). He placed a flat metal pattern covered with the uranium salt on a photographic plate wrapped in black paper and left it in bright sunlight so that the phosphorescence would be of the greatest possible intensity. Four hours later



Becquerel developed the plate and saw a sharp outline of the pattern on it. He repeated his experiment again and again but the result was always the same. Finally, on February 24, 1896, the scientist reported to the sitting of the French Academy of Sciences that a phosphorescing substance, such as double uranyl and potassium sulphates, placed in light emitted an invisible radiation which passed through black opaque paper and reduced the salts of silver on the photographic plate.

Two days later Becquerel decided to continue his experiments, but, as though to spite him, it was overcast and without the sun no phosphorescence could take place. Annoyed with the weather, the scientist put away the slides he had prepared together with samples of uranium salts in his desk and left them there for several days. Finally, on the morning of March 1, the wind cleared the Parisian sky and the city was flooded with sunlight. Becquerel hurried to his laboratory and got the slides out in order to place them in the sun. But being a very pedantic experimenter, he decided at the last moment to develop them, although it would be perfectly logical to assume that nothing could have

happened over the preceding few days: the plates were in a dark drawer and without light not a single substance would phosphoresce. At that moment the scientist did not suspect that the photographic plates which had cost him a few francs would become a priceless treasure several hours later and that March 1, 1869, would go down for ever in the history of world science.

What Becquerel saw on the developed plates struck him with incredulity: the black outlines of the samples were sharply silhouetted on the light-sensitized layer. That meant that phosphorescence had nothing to do with it. But what rays did the uranium salt emit? Becquerel continued his experiments with other uranium compounds, even those that were not characterized by phosphorescence or had been kept for years in a dark place, and every time he had an image on the plate.

Becquerel came to the conclusion, although as yet not very definite, that uranium was "the first example of a metal revealing a property similar to invisible phosphorescence."

At the same time another French chemist Henry Moissan developed a process of obtaining pure metallic uranium. Becquerel asked him for some uranium powder and established that the invisible emanations from pure uranium were much more intense than from its compounds and that this property remained unaffected under widely different experimental conditions, and in particular, when uranium was heated to high or cooled to low temperatures.

Becquerel did not hurry to publish his new results: he was waiting for Moissan to report on his own very interesting research first. Such was the code of ethics in science. Then the day came: November 23, 1896. Moissan delivered a report to the Academy of Sciences on his development of the process of obtaining pure uranium and Becquerel told about the newly-

discovered property inherent in that element, namely a spontaneous fission of the nuclei of uranium's atoms.

Becquerel's discovery ushered in a new epoch in physics, an epoch of transmutation of elements. From then on the atom could no longer be considered one and indivisible. Science was embarking on a road into the depths of the atom, the brick from which the material world is built.

Uranium naturally had now become the focus of the scientific interest. At the same time physicists were intrigued by whether uranium was the only radioactive element in nature.

This question was answered by the outstanding physicists, husband and wife Pierre Curie and Marie Skłodowska-Curie. By means of an instrument designed by her husband Marie Curie studied a great number of metals, minerals and salts for radioactivity. The physicists had to work in extremely difficult conditions. Their laboratory was in an abandoned wooden shack they had found in the yard of some building in Paris. Marie Curie wrote in her diary: "This was really a wooden barracks with an asphalt floor and glass roof which offered a poor protection from the rain, empty but for some old wooden tables, an iron stove which was never warm enough, and a blackboard which Pierre liked to use so much. There were no hoods for experiments with noxious gases and we had to work with them in the yard, when the weather was good, or indoors with 'windows' open". In his diary Pierre Curie remarked that sometimes the temperature in their shack was only 6°C.

Getting all the necessary raw materials was also a problem. Uranium ore was very expensive and the scientists could not buy the amount they needed on their modest means. They approached the Austrian government, asking it to sell them, at a low price, some wastes from the production of uranium salts which were

used in Austria for dyeing glass and porcelain. Their request was backed by the Vienna Academy of Sciences and several tons of the wastes were delivered to the Curie laboratory.

Marie Curie worked with amazing perseverance. Her research confirmed Becquerel's conclusion that pure uranium's radioactivity was much higher than that of any of its compounds. The results of hundreds of experiments also confirmed it. But Marie Curie studied more and more substances until there was an entirely unforeseen development: she discovered that chalcocite and pitchblende ores of Bohemia affected the instrument much more actively than uranium. The conclusion was self-evident: the two minerals contained some unknown element characterized by even a higher fissionability. They called it polonium in honour of Poland, Marie's homeland.

Marie Curie did not stop there. She continued her intensive research and made another discovery: an element hundreds of times more radioactive than uranium. Scientists gave it the name "radium" meaning "ray" in Latin.

The discovery of radium had somewhat distracted the scientific world from uranium. Scientists had remained rather cool to it for about forty years. The engineers' attitude was even cooler. One technical encyclopaedia printed in 1934 asserted, "Elementary uranium has no practical application." That respectful publication did not distort the state of affairs, but in just a few years the conception of the possibilities of uranium underwent a remarkable transformation.

At the beginning of 1939 there were two important developments. The first was a paper from Frédéric Joliot-Curie to the French Academy of Sciences entitled "Experimental Proof of Explosive Fission of the Uranium and Thorium Nuclei Under the Action of Neutrons". The second was a communication from the

German physicists Otto Frisch and Lise Meitner published in the English magazine *Nature*. It was entitled "Uranic Fission under the Action of Neutrons: A New Type of Nuclear Reaction". Both papers dealt with a hitherto unknown phenomenon observed in the nuclei of uranium, the heaviest element.

But a few years before that, a serious interest in uranium was displayed by the "boys", as a group of young gifted physicists under Enrico Fermi at the University of Rome was called. Neutron physics, a branch almost unexplored, was what attracted those physicists.

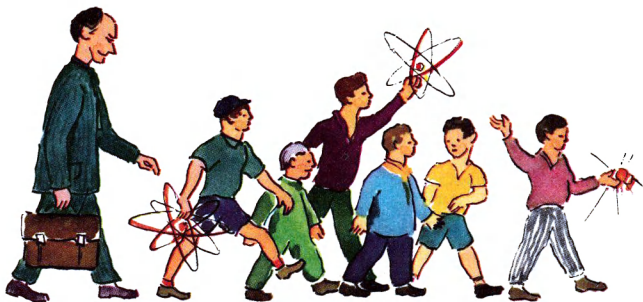
It was found that as a rule the nuclei of one element irradiated by neutrons turned into the nuclei of another occupying the next square in the Periodic Table. But what if the last, 92nd, element—uranium—is irradiated by neutrons? Then an element occupying the 93rd square must emerge, an element that even Nature herself was powerless to create?

The "boys" liked the idea very much: it was extremely interesting to know what an artificial element would be like, how it would look and behave. But when they irradiated uranium they had obtained not one element as expected, but at least

a dozen. There was some mystery in uranium's behaviour. Enrico Fermi sent a report to a scientific journal saying that it was likely a 93rd element had been produced but he could not be sure, because he had no definite proof. On the other hand, there was proof that some other elements were present in the irradiated uranium. But what elements?

Marie Curie's daughter, Irène Joliot-Curie attempted to find an answer to the riddle. She repeated Fermi's experiments and carefully studied the chemical composition of uranium after irradiation with neutrons. The result was stunning: uranium contained the element lanthanum situated somewhere in the middle of the Periodic Table, i.e. very far from uranium.

When the same experiments were repeated by the German physicists Otto Hahn and Friedrich Strassman they discovered not only lanthanum in uranium but also barium. One mystery on top of another! The two scientists told the well-known physicist Lise Meitner about their work. Now several prominent scientists had begun working on the uranium problem. After a while Joliot-Curie, followed by Lise Meitner, arrived at one and the same





conclusion: when a neutron hit a uranium nucleus it split it into two, as it were, which explained the appearance of lanthanum and barium, the elements whose atomic weight was about half that of uranium.

The American physicist Luis Alvarez learned about that discovery one January morning in 1939 while sitting in a barber's chair. He was leafing through a newspaper when suddenly his eyes caught an inconspicuous heading: "Uranium Atom Split in Two".

The next moment he was out of the chair, and to the utter amazement of the barber and the other visitors in the shop, rushed into the street with the towel still tucked in around his neck and his hair half done. Oblivious of people around, the physicist was racing to his laboratory at the University of California to report the great news. His colleagues, who were at first puzzled by his strange appearance, immediately forgot it when they learned about the sensational discovery.

And that was truly a sensation in science. But Joliot-Curie had also established another fact: the splitting of the uranium nucleus was in the nature of

an explosion that sent splinters flying in all directions at great speed. As long as it was possible to split only some of the nuclei, the energy of the splinters could only warm up the lump of uranium. But if the number of the split nuclei would be large, a colossal amount of energy would be released.

But where could neutrons be obtained in numbers adequate to bombard simultaneously a large number of uranium nuclei? For the neutron sources known to scientists produced thousands of millions of times fewer of them than required. That was taken care of by Nature herself. Joliot-Curie established that when a neutron hit a nucleus the latter also released several neutrons. When hitting neighbouring nuclei those neutrons were to cause further splitting, that is, a chain reaction was to set in. Since those processes would last for a few millionths of a second, the energy to be released would be tremendous and an explosion imminent. Everything was clear it seemed. But it was also true that lumps of uranium had been bombarded by uranium many times and none of them had ever exploded, meaning to say that no chain reaction had taken

place. Apparently some other factors were essential. But what? That was a question Joliot-Curie could not yet answer.

It was answered, however, the same year, by the young Soviet physicists Ya. B. Zeldovich and Yu. B. Khariton, who outlined two ways of developing a nuclear chain reaction. The first was to increase the size of the uranium lump, since many neutrons produced during bombardment could become released from it without having met a single nucleus on their way. An increase in the uranium mass naturally increased the chances of neutrons hitting the target.

The second way was to enrich uranium by the isotope 235. The point is that native uranium has two major isotopes with the atomic weights 238 and 235. The nucleus of the first contains three extra neutrons. The isotope uranium-235 which is "poor" in neutrons greedily absorbs them, much more so than its "well-off" brother which under ordinary conditions does not even split on absorbing a neutron but transforms it into a different element. Subsequently scientists used this property for creating transuranium elements. But as far as the chain reaction is concerned the "indifference" of uranium-238 to neutrons is destructive: it dampens the process before it has a chance to gain strength. But the more of the isotope 235 uranium contains, the more intense will be the chain reaction.

In order to start the reaction, however, the first neutron is needed, the "match" that will give rise to the atomic "conflagration". Scientists could naturally make do with the conventional neutron sources, those they used in their research before. True they were not very convenient, but they could be used. But wasn't there a better "match"?

There was. It was found by the Soviet physicists K. A. Petrzhak and G. N. Flerov. Studying uranium between 1939 and 1940, they proved that its nuclei were capable of spontaneous disintegration. Their conclu-

sion was borne out by the results of the experiments which had been conducted at a Leningrad laboratory. However, there was the possibility that uranium disintegrated not by itself but under the influence of, say, cosmic rays whose bombardment the Earth was constantly experiencing. That meant that the experiments had to be conducted deep underground where no cosmic rays could penetrate. The young scientists discussed the matter with the leading Soviet atomic researcher Igor Kurchatov and decided to carry out their experiment at a Moscow Metro station. The People's Commissariat for the Railways had no objections and soon about three tons of equipment was brought by the researchers to the office of chief superintendent of the Dynamo Metro Station situated 50 metres below the ground level.

That day the blue trains were speeding past the platform just as usual and the thousands of people going up and down the escalators had no idea that not far from them experiments were being conducted the significance of which could hardly be overestimated. When the results were obtained they were the same as those in Leningrad. There was no doubt that uranium nuclei could disintegrate spontaneously. But in order to notice it the highest skill was required of the experimenter: in one hour only one in 60 000 000 000 000 nuclei disintegrated. A drop in the ocean, really.

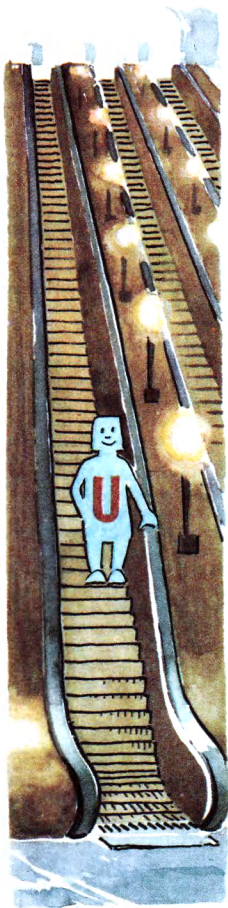
Thus K. A. Petrzhak and G. N. Flerov wrote the concluding page to that part of the biography of uranium which preceded the launching of history's first nuclear chain reaction. It was accomplished by Enrico Fermi on December 2, 1942.

Fleeing from fascism at the end of the 1930's, Fermi, like many other scientists, was compelled to emigrate to the United States. He wished to continue his experiments there but he did not have enough money. The American government had to be convinced that Fermi's

experiments would produce a powerful atomic weapon which could be used against fascism. The American government was approached by Albert Einstein, the celebrated scientist of world reknown. He wrote to President Roosevelt saying that the work of Fermi and Szilard gave grounds for hope that the element uranium could in the near future be converted into a new important source of energy. Einstein asked the President to give financial backing to uranium research. Being aware of Einstein's enormous authority and the gravity of the international situation, Roosevelt gave his consent.

At the end of 1941 Chicago residents witnessed unusual activity, which had nothing to do with sports, in one of their stadiums. Loaded trucks pulled up at the gate one after another and numerous guards did not let strangers even come near the fence. There, in the tennis courts beneath the western stands, Fermi was preparing for the most dangerous experiment in history—controlled chain reaction of splitting uranium nuclei. The work to mount the world's first nuclear reactor went on day and night for a whole year.

Came the morning of December 2, 1942. The scientists had not slept a wink the previous night, checking and rechecking their calculations. Small wonder: the stadium was in the centre of a big city populated by millions of people, and though the calculations showed that the reaction would be slow, that is, would not be in the nature of an explosion, they could not risk the lives of hundreds of thousands. The day had long since begun, the time for breakfast was long overdue, but no one remembered about it. Tension had reached its peak but Fermi was in no hurry: people had to be given a chance to rest a bit, to have a release from tension in order to be able to think over everything once more. Utmost caution was essential. When all were ready and waiting for the



command to begin Fermi did something that went down in the history of science: he said that it was time for lunch.

When all were back in their posts, the experiment began. Minutes of nervous tension when all eyes were fixed on the instruments were crawling slowly when suddenly the neutron counters came alive, clicking wildly in their mad haste. The chain reaction had set in. That happened at 15 hours 25 minutes, Chicago time. The atomic fire was allowed to burn for 28 minutes and then, on Fermi's command, it was stopped.

One of the scientists went to the telephone to report to the authorities. He pronounced the coded message: "The Italian seafarer has made it to the New World". That meant that the Italian scientist Enrico Fermi had released the energy of the atomic nucleus, proving that man could control and use it as his will dictated him.

But one will can be the opposite of another. In those years the chain reaction was above all viewed as a stage on the way to the atomic bomb. And that was where the American atomic researchers were heading. The atmosphere surrounding this work was tense, but still some funny incidents associated with it were recorded in that period.

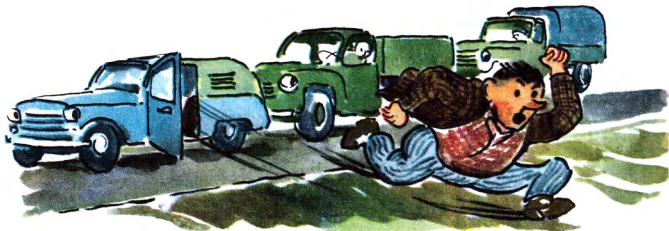
In the autumn of 1943 it was decided to make an attempt to take out Niels Bohr

from occupied Denmark to the United States so that he could share his great knowledge and talent. On a dark night the scientist was brought to Sweden in the guise of a fisherman, in a small shabby boat secretly guarded by British submarines. From there he was to be taken by plane to Britain and then to the United States.

Bohr's sole luggage was a bottle, an ordinary green Dutch beer bottle in which he was keeping from the Germans the precious heavy water: many nuclear physicists held that heavy water could be used first and foremost to slow down the neutrons in a nuclear reaction.

The long flight wore the scientist out considerably, but the first thing he asked about when he recovered a little was about the bottle. One can imagine his disappointment when he discovered that he had fallen victim to his own absent-mindedness: he was holding a bottle of real Dutch beer and the bottle with heavy water was left in the refrigerator back home.

The first small lump of uranium-235 intended for the atomic bomb and produced at the gigantic plants in Oak Ridge, Tennessee, was sent with a special messenger to Los Alamos situated somewhere among the desolate canyons of New Mexico where this lethal weapon was being developed. The messenger who was





also the driver, had not been told what the little box he was to carry contained, but he had heard plenty of horror stories about the mysterious "rays of death" that were being created in Oak Ridge. The longer he drove the more nervous he became, until finally he decided that the minute the box hidden behind him began to behave suspiciously, he would abandon the car and run for his life.

When he was driving over a long bridge the messenger suddenly heard a loud report behind. As though catapulted, he jumped out of the car and raced away like a sprinter. He had run a good distance and stopped, panting for breath. Then he realized that nothing had happened to him and he ventured to take a look around. He saw a long line of cars honking for him and went back to continue his journey.

No sooner had he touched the steering wheel, than another shot rang out. His self-protection instinct had literally thrown him out of his seat again and sent him on a new race. It was only after a furious policeman had overtaken him in a motorcycle and seen his government papers that he learned that the reports were coming from a nearby testing ground where new shells were being tried out.

The work in Los Alamos was shrouded in deep mystery. All the prominent scientists there went under assumed names: Niels Bohr was Nicholas Baker, Enrico Fermi was Henry Farmer and Eugene Wigner was Eugene Wagner.

One day when Fermi and Wigner were leaving the premises of one secret plant, they were stopped by a guard. Fermi showed him his pass issued to Farmer and Wigner could not find his. The guard had a list of those who could come and go. When he asked Wigner his name the absent-minded physicist mumbled "Wigner", but immediately checked himself and answered "Wagner". The guard's suspicions were immediately aroused: his list had "Wagner" on it but no "Wigner". He turned to Fermi whom he knew well by sight and said, "Is this man Wagner?" "Yes, his name is Wagner. This is as correct as that I'm Farmer," Fermi suppressed his smile and sounded convincing. The guard let them through.

Somewhere in the middle of 1945 the work on the atomic bomb which had cost two thousand million dollars was completed and on August 6 the gigantic fiery "mushroom", obscured the sky over Hiroshima, claiming tens of thousands of

human lives. That event was a black day in the history of civilization. The greatest achievement of the human brain caused the greatest human tragedy.

The scientists and the public at large were faced with the alternative: to continue improving the atomic weapon or make the colossal energy of the nucleus serve human ends. The first step on this latter way was made by Soviet scientists headed by Academician Igor Kurchatov. On June 27, 1954, Radio Moscow reported an event of crucial importance: "The efforts of Soviet scientists and engineers to build the world's first atomic power station with a capacity of 5000 kilowatts have been crowned with success." For the first time in history the electric lines conducted current born of the atoms of uranium.

The view overwhelmingly expressed by the mass media of those days was that the

atomic power plant was of incomparably greater significance than the birth of the atomic bomb.

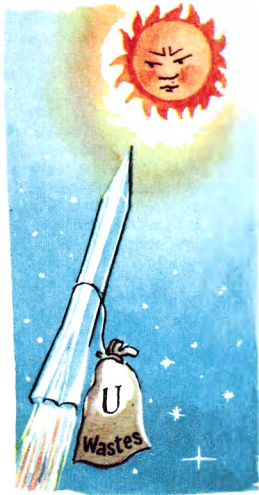
Thus, the age of the nuclear power industry was ushered in. Uranium became the peaceful fuel of the 20th century.

Another five years had passed and the world's first atomic ice breaker the *Lenin* came off the Soviet building slips. To make her engines operate at full capacity (44000 horse power!) it is necessary to "burn" only a few dozen grams of uranium. A small lump of this nuclear fuel can replace thousands of tons of oil or coal, a load which conventional steamships literally have to drag along if they are on the way, say, from London to New York. Meanwhile the *Lenin* with several dozen kilograms of uranium on board can do her job in the Arctic for three years without refuelling.

In 1974 even more powerful (75000 horsepower!) atomic icebreaker the *Arktika* was launched. Three years later (August 17, 1977), having navigated the hitherto inaccessible central ice sheet of the Arctic Ocean, the *Arktika* reached the North Pole, realizing the age-old dream of seamen and polar explorers.

The share of the nuclear fuel in the world power balance becomes increasingly larger. Several years ago the first industrial atomic power station working on a fast-neutron reactor was commissioned in the Soviet Union. The distinguishing feature of these reactors is that they can operate on the inexpensive uranium-238 (and not the scarce uranium-235) which is the most widely distributed uranium isotope in nature. Furthermore, this reactor not only releases colossal energy but also the artificial element polonium-239 which is also fissionable, hence can itself be a nuclear power source. In the words of Academician Kurchatov, "You burn coal in the furnace and together with the ashes pull out even more coal."

Japanese researchers have designed



a plant for the extraction of uranium from sea water. This uranium is several times more expensive than that produced on the ground, but it is meant to help "earth-bound" uranium when the country's need for it is expected to increase dramatically within the next few years owing to the planned rise in the atomic power industry.

The advantages of nuclear fuel cannot be disputed. But its use involves many difficulties of which radioactive waste management is one of the greatest. What is to be done with those dangerous "ashes"? Should they be dumped in the seas and oceans in special containers or buried deep underground? The truth is that neither of these methods can fully solve the problem, because the lethal substances would still remain on our planet. An idea recently expressed in the USA was to send the

containers out to space, to some out of the way celestial body. The author of the idea suggested that the radioactive wastes should be loaded onto "freight" spaceships and sent in the direction of the Sun. It goes without saying that such "parcels" are too expensive today, but according to some optimists, ten years or so from now such transport operations may become perfectly feasible.

It doesn't take an especially imaginative mind to realize what a great future uranium has before it. Its energy will feed tomorrow's space rockets, supply underwater towns and artificial islands with energy sources for decades to come, bring water into the deserts, reach the inner depths of the Earth and change the climate. In this sense it is perhaps correct to say that uranium is the most wonderful metal Nature has ever created.



ISBN 5-03-000054-2